Journal and Proceedings

OF

The Royal Society of Western Australia.

PATRON: HIS MAJESTY THE KING.

Volume IV.
1917 - 1918.

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LIST OF MEMBERS.

1st July, 1918.

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Bird, Mrs. A. M., The Old Farm, Albany.
Cooke, Prof. W. E., M.A., F.R.A.S., Observatory, Sydney, N.S.W.
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ORDINARY MEMBERS.

Alder, Miss, 237 Beaufort Street, Perth.
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Allum, Miss Enid, 232 St. George's Terrace, Perth.
Andrews, Cecil, M.A., View Street, Cottesloe.
Bell, W. G., B.Sc., Geological Survey, Perth.
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Bowley, Harry, Geological Survey, Perth.
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Creeth, Miss M. E., Wilson Street, West Perth.
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Feltdmann, F. R., Geological Survey, Perth.
Grasby, W. Catton, F.L.S., West Australian Chambers, Perth.
Hancock, W. J., M.I.C.E., M.I.E.E., P.W.D., Perth.
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Montgomery, Mrs. A., 30 Richardson Street, West Perth.
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O'Connor, Dr. M., Weld Club, Perth.
Parkinson, W. C., Carnegie Institution Magnetic Observatory, Moira.
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Shelton, Mrs., 20 Kershaw Street, Subiaco.
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Sutherland, T. G., Fremantle Trading Co., Fremantle.
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Talbot, H. W. B., Geological Survey, Perth.
Taylor, W. H., Tramway Department, Perth.
Thompson, James, Esplanade, Cottesloe.
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ASSOCIATE MEMBERS.

Allen, F. B., M.A., B.Sc., Technical School, Perth.
Campbell, W. D., A.K.C., F.G.S., A.M.I.C.E., Penlake, Lucknow Street, Willoughby, N.S.W.
Clark, J. S., 54 Jewell Street, Perth.
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Cowan, Miss H., 52 York Street, Boulder.
Creeth, Mrs. F. B., Orna, Broome Street, Cottesloe Beach.
Davy, Miss M., 9 Ord Street, Perth.
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Farquharson, R. A., M.A., M.Sc., A.O.S.U., F.G.S., Geological Survey, Perth.
Gribble, Rev. E. R., Forrest River Mission, Wyndham.
Hall, A. J., 7 Ruby Street, North Perth.
Hardy, G. H., Public Museum, Hobart, Tasmania.
Lapsley, R., Fire Station, Perth (absent at the war).
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Lovegrove, Dr. F. (absent at the War).
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Pearson, H. E., B.Sc., Modern School, Perth.

Rawson, V. S., Explosives and Analytical Department, Wellington Street, Perth.
Shelton, Miss K., 39 St. George's Terrace, Perth.
Shelton, W. E., Modern School, Perth.
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Steedman, H., Suburban Road, Victoria Park.
Wright, A. R. L., L.R.I.B.A., P.W.D., Perth.
Watson, Mrs. Heyworth, Inchbrayock, South Perth..
Watson, Miss P., Inchbrayock, South Perth.
Zabel, Mrs. F., 621 Hay Street, Perth.

CORRESPONDING MEMBER.

Hedley, C., F.L.S., Australian Museum, Sydney.

STUDENT MEMBER.

Montgomery, S. K., 20 Richardson Street, West Perth (absent at the War).

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Royal Societies of New South Wales, South Australia, Tasmania, Queensland, and Victoria.
University of Tasmania.
Field Naturalists' Club of Victoria.
Department of Agriculture, Victoria.
Committee Advisory Council of Science and Industry.
Department of Agriculture, N.S.W.
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Department de l'Agriculture, de l' Industrie et du Commerce, Buitenzorg, Java.

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Royal Colonial Institute.
British Museum.
Secretary for State for India in Council.

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Senor Director del Cuerpo de Ingenieros de Minas del Peru.

PROCEEDINGS OF THE ROYAL SOCIETY OF WESTERN AUSTRALIA.

August 14, 1917.—The President, Mr. A. Montgomery, in the Chair. A paper which had been presented at the meeting dated June 12 was read by Mr. Talbot, entitled "*Geological Results of an Expedition to the South Australian Border.*" The authors were Mr. H. W. B. Talbot and Mr. E. de C. Clarke. The paper was illustrated by lantern slides.

September 11, 1917.—The President, Mr. A. Montgomery, in the Chair. The President referred to the loss sustained by the death of Mr. F. S. Brockman, the Surveyor General. The Hon. Walter Kingsmill, Mr. A. Knapp, and Mr. Wilfred Parkinson were elected as ordinary members, and Mrs. F. Zabel and Mr. Shelton as associate members. A paper on the "*Decimalisation of the British Currency*" was laid on the table by Mr. F. E. Allum, who then gave to the members a *résumé* of its contents. Mr. Shields, Mr. Sutton, and Mr. Montgomery took part in a discussion which followed.

October 9, 1917.—The President, Mr. A. Montgomery, in the Chair. Mr. H. B. Curlewis read a paper, illustrated by lantern slides, on "*Earth Tremors and Subterranean Noises in Western Australia.*" Mr. Gibb Maitland, Prof. Ross, and Mr. A. Montgomery took part in a discussion which followed. Mr. Cecil Andrews exhibited some specimens of *Orobanche cernua,* a native parasite plant which grows on an introduced host. The specimens were growing on a leguminous host, the only host observed up to date.

November 13, 1917.—The President, Mr. A. Montgomery, in the Chair. The Hon. Walter Kingsmill gave a lecture on the "*Geography and Constitutional History of the Malay States.*"

December 11, 1917.—The President, Mr. A. Montgomery, in the Chair. Mr. F. Aldrich, Chief Inspector of Fisheries, was elected an ordinary member of the Society. Arising out of a letter received from the "League for the Promotion of Post-War Industries," a discussion was opened by the President on "*Possible Fields of New Industries for the State.*" Prof. Ross and Messrs. Downes and Hancock dealt mainly with the question of the importance of research. Mr. Simpson stated that some steps had been taken with regard to promoting the manufacture of Cream of Tartar, Portland Cement, Insulating Materials, Insecticides, and Sheep-dip. Prof. Dakin

drew attention to the necessity of the scientific treatment of the agricultural industry, and expressed regret at the Government's recent action in reducing the staff of the Laboratory for plant pathology, the cost of which would be many times repaid by the knowledge gained as to the means of reducing destructive pests. The President undertook to convey to the League a *résumé* of the statements and opinions which had been given.

March 12, 1918.—Mr. W. J. Hancock, Vice-President, in the Chair. Mr. G. L. Sutton, Commissioner for the Wheat Belt, read a paper, illustrated with lantern slides, on the "*Bulk Handling of Wheat*," showing the great advantage it would have for this State over the present method of bag handling. On the recommendation of the Council, Mrs. Bird, of Albany, was made an honorary member of the Society, in recognition of her long and zealous patronage of science. She was one of the foundation members of the original Mueller Botanical Society.

April 9, 1918.—The President, Mr. A. Montgomery, in the Chair. Prof. W. J. Dakin read a paper, illustrated by lantern slides and specimens and microscopic preparations, on "*Insect-Eating Plants, with special reference to the West Australian Pitcher plant Cephalotus.*"

Mr. W. B. Alexander exhibited a specimen of *a newly discovered marsupial.* It had been sent alive from Violet Valley Station, East Kimberley, but subsequently died at the Zoological Gardens, Perth. The animal bears certain resemblances both to the Australian opossum and to the Malay cuscus.

May 14, 1918.—The President, Mr. A. Montgomery in the Chair. Mr. A. J. Hall exhibited and described two dozen paintings of *wild flowers* collected at Broomehill. Mr. E. S. Simpson exhibited and described (1) a new source of commercial potash, viz. *Jarosite,* from Northampton, and crude potassium sulphate extracted from it, and (2) some *secondary calcite* from Mount Henry, near Perth. Mr. T. Blatchford exhibited and described *miocene fossil sponges* found in the neighbourhood of Hamersley River. Mr. Montgomery exhibited *fossils found in sandstone* on a path in the King's Park, Perth, which had probably come from near Fremantle; also an *ammonite* from Glastonbury Abbey, England.

June 11, 1918.—The President, Mr. A. Montgomery, in the Chair. Prof. W. G. Woolnough was elected an ordinary member, and Mrs. Paton an associate member. A vote of thanks was passed to Dr. F. Stoward for his services as librarian and regret expressed that he was leaving the State. Mr. Montgomery then delivered his Presidential Address, the subject of which was "*The Closer Cooperation between Science and Industry.*"

July 9, 1918.—Annual Business Meeting and Conversazione. The following officers were duly elected for the coming year:—

President—Mr. W. J. Hancock, M.I.C.E.

Vice-Presidents—Mr. G. L. Sutton and Mr. E. S. Simpson.

Secretary—Mrs. W. J. Dakin.

Treasurer—Mr. F. E. Allum.

Librarian—Mr. W. E. Shelton.

Council—Mr. A. Montgomery; Prof. A. D. Ross, D.Sc.; Prof. W. J. Dakin, D.Sc.; Mr. C. E. Lane-Poole; Dr. D. D. Paton, M.A., M.B.; Mr. A. Gibb Mait'and, F.G.S.

Copies of the Annual Report and the Statement of Receipts and Expenditure were handed to each member and taken as read. Various exhibits were inspected and the incoming President, Mr. W. J. Hancock, installed and welcomed by the Society.

ROYAL SOCIETY OF WESTERN AUSTRALIA.

Annual Report for year 1917-18.

Ladies and Gentlemen,

Your Council begs to submit the Annual Report for the year ending 30th June, 1918.

The Treasurer's report shows a credit balance of £38 18s. 9d., which will be sufficient to pay the cost of printing Vol. III. of the Society's journal, which will shortly be available.

There are 93 members of the Society, 19 being associate, one student, one corresponding, and eight honorary members. Four members are serving at the Front. Eight new members have been elected during the year. It is with regret that we have to record the death of a prominent member of the Society, that of the Surveyor General, Mr. F. S. Brockman.

In November, 1917, the Interstate Forestry Conference was held in Perth, and the Society took the opportunity of holding a special meeting on 20th November, at which two visiting members, viz., R. Dalrymple Hay, Esq., Chief Commissioner for Forests, New South Wales, and W. Gill, Esq., Conservator of Forests, South Australia, gave addresses.

In September, 1917, it was decided that the Society should become a member of the League for the Promotion of Industries and Post-War Projects.

In December, 1917, the following resolution was passed:—"That this Council recommends that Mrs. Bird, of Albany, be made an honorary member of the Royal Society by reason of her zealous patronage of Science and her long association with the Society, having been one of the foundation members of the old Mueller Society"; and in March, 1918, Mrs. Bird was elected an honorary member of the Society.

During the year a paper, written on the Flora of the Kimberley District of Western Australia by Mr. Fitzgerald, was given to the Society by Mr. Maiden of the Australian Museum, Sydney, to be published in this Society's journal.

Arrangements have now been made, with the assistance of the Hon. Ministers of Agriculture and Forestry, whereby Mr. Fitzgerald's paper will be printed at no extra cost to the Society.

During the year there have been 12 meetings of Council, and the attendances of members are as follows:—Mr. Montgomery, 12; Mr. Hancock, 7; Mr. Sutton, 10; Mr. Simpson, 8; Mr. Allum, 10;

Dr. Stoward, 6; Professor Dakin, 6; Professor Ross, 6; Mr. Curlewis, 6; Mr. Lane-Poole, 5; Mr. Gibb Maitland, 1; and Mrs. Dakin, 11.

At the meeting in June a vote of thanks for his services to the Society, as Librarian, was passed to Dr. Stoward, who is leaving the State.

Your Council would also like to acknowledge the courtesy of the University in allowing the Society the use of some of its rooms on different occasions through the year.

There have been nine general meetings held during the year, and the following papers have been given:—

1. "The Decimalisation of the British Currency." By F. E. Allum.
2. "Earth Tremors and Subterranean Noises in W.A." By H. B. Curlewis, B.A.
3. "The Malay States." By W. Kingsmill, M.L.C.
4. "The Bulk Handling of Wheat." By G. L. Sutton, the Commissioner for the Wheat Belt.
5. "Western Australian Pitcher Plant." By Professor Dakin.
6. "The Closer Relations of Science and Industry." By A. Montgomery. (Presidential Address.)

The usual exchanges of the Society's Journal with the publications of various institutions have been made by the Librarian.

(Signed) A. MONTGOMERY, President.
(Signed) C. M. G. DAKIN, Hon. Secretary.

ROYAL SOCIETY OF WESTERN AUSTRALIA.

Statement of Receipts and Expenditure during the Year ended 30th June, 1918.

Receipts.	£	s.	d.	Expenditure.	£	s.	d.
Subscriptions	67	9	0	Printing Vol. II. ...	65	1	0
				Printing maps for Vol. III.	3	17	6
Interest on Banking Account	0	13	0	Fees to Trustees of Museum	12	0	0
Author's Fees for extra reprints of papers ...	6	15	0	Subscription to League for Promotion of Industries and Post War projects	1	1	0
				Postage and Petty Expenses	5	18	11
Total Receipts ...	74	17	10	Total Expenses ...	87	18	5
Balance in hand at beginning of year—				Balance in hand at end of year—			
At Bank ...£51 15 0				At Bank... £38 4 8			
In Cash ... 0 4 4				In Cash ... 0 14 1			
	51	19	4		38	18	9
	£126	17	2		£126	17	2

(Signed) F. E. ALLUM,
Hon. Treasurer.

Audited and found correct—

(Signed) {A. O. WATKINS.
A. KNAPP

4th July, 1918.

THE JOURNAL

OF

THE ROYAL SOCIETY

OF

WESTERN AUSTRALIA.

VOL. IV.

Presidential Address.

THE MOVEMENT FOR CLOSER APPLICATION OF SCIENCE TO INDUSTRIES.

A. Montgomery, M.A., F.G.S. (President).

The subject taken for to-night's address is one very much before scientific workers at the present time, the movement for the closer application of Science to Industries being a very widespread one throughout not only the British Empire and the domains of its allies, but also more or less throughout all other countries of the globe. It is one of the most notable results of the great war which has afflicted the world for now nearly four years, and arises from the wider recognition by the nations of the urgent need of using to the full all the resources of science to improve industrial production.

This need has always been well recognised by the leaders of thought in all classes of the community, but the demands of the war seem at last to have brought it better home to the public in general that science is not a mere unintelligible pursuit confined to a few learned persons, but a real aid to and necessity of industrial progress. For this recognition we owe more than a little to the enemy, who have long vaunted in the most arrogant manner their alleged claims to superiority in scientific attainment, and have attempted to demonstrate it in the war by using poisonous gases, flame-throwers, and all sorts of other devilish contrivances to win their way to victory, not omitting to debase even psychology to the vile uses of their doctrine of "frightfulness." To meet their novel

methods of attack we have had to call more and more upon the aid of our own and our allies' men of science, to devise means of counteracting their evil devices, and to pay them back in their own coin with interest. This has brought it home to even the most unthinking "man in the street" that we should be lost if our men of science were not able to reply to the devices of the enemy. It has come upon the bulk of the community also as a great shock that in many lines of industrial production the British nations had become dependent on foreign and even upon now hostile countries for materials and manufactures of necessaries of existence, and were unable to obtain their supplies as hitherto, and it has been well impressed upon them that the only hope of recovering our position is by invoking the aid of science to enable us to become again self-supporting and self-defensive. The war has caused a revision of many old ideas as to freedom of trade and the gospel, beloved by economists, of buying in the cheapest and selling in the dearest markets, and we have had to recognise that defence of the national existence is a matter of more consequence than any merely trading considerations. We see now that whatever else we do, we shall have to provide for all necessities for defence and subsistence out of resources under our own control, with the least possible reliance for them upon other people with whom our relations may become hostile. This is very particularly the case with Australia, for the war has brought us face to face with the fact that if we had to depend upon our own resources Australia is hopelessly unprepared to meet a powerful enemy, especially if that enemy be a maritime Power which could cut us off from sea communication with the outside world. Our means of making munitions of war are utterly inadequate to cope with a war demand, and many war necessities we are not in a position to make at all. It is obvious, therefore, that Australia must not be content to remain merely a producer and exporter of primary products, but must institute manufacturing industries, even at much pecuniary sacrifice, which will enable us to provide fully for our own defence in case of necessity. No sooner do we look round to see how such manufactures may be started than we begin to appreciate the fundamental position occupied by science in regard to them, and the absolute necessity of co-ordinating all the resources of science and industry to bring about success.

On the outbreak of war there was immediately great enthusiasm on the part of all classes of the community to take some part in making good our national deficiencies; but with all the good will in the world many of these efforts have been very ineffective for want of good direction and systematic organisation. There has been much duplication and overlapping of effort, various sporadically formed bodies all trying to do the same things. They are like the crowd at a house on fire, all willing and anxious to do what each man can do to help, but lacking in combination and effecting little

in consequence. When the fire brigade arrives the position changes at once, order taking the place of chaos, and systematic and directed work that of undisciplined endeavour. Quite the same course must be followed if we are to make the best use of the energies directed towards establishment of industries: the various detached efforts must be brought together into more effective combinations and under more uniform control. It is not to be denied that some amount of competition and rivalry among the various workers on the same lines is often of much value in producing the best effects, just as the friendly rivalry of different fire brigades may be of much advantage at a big conflagration, but the main thing is that the whole of the work should be organised and systematised to the one end, and that there should be a minimum amount of duplication of work.

It will be useful to review briefly the steps which are being taken in the British Empire to co-ordinate science and industry, and to discuss somewhat more fully the position in the same regard of Australia in general and our own State more particularly.

Throughout the world there are a great number of organisations more or less connected with science and industry, comprising Government departments, universities, technological colleges, scientific institutes for research, and a vast number of societies, associations, and similar bodies covering almost every department of the subject from pure science to pure trade, and including men whose specialities lie upon educational, investigational, professional, technical, and manufacturing lines. There are also very many private firms and private persons who maintain laboratories and workshops in which much investigation and experimentation are carried on. All have their own special spheres of operation, and apply science to industry in a greater or less degree, and each is liable to have special information and experience upon certain aspects of operations in which several are more or less concerned. The great object of organisation is to bring together from all these sources all the knowledge that can be concentrated upon any particular industrial problem. This method has been happily referred to as one of "massed attack," and has given valuable results in many different lines already.

Recognising the necessity of organising the national forces in this way, and that such organisation would require to be in the very closest touch with the Government itself, the Imperial Government appointed a Committee of the Privy Council "for the organisation and development of Industrial Research," consisting of certain members of the Privy Council, who were themselves of distinguished scientific attainments, assisted by an advisory council of men eminent in science and industry. It will be seen that this committee was an actual part of the Government itself, and so in the inmost councils of the nation, giving it a standing and authority much

higher than that of any merely departmentally organised body. The advisory council might really be responsible for any action recommended, but before it could be adopted by the Government the council would have to convince the Committee of the Privy Council that its recommendations should be endorsed by the Government. Some stress is being laid on this point of the constitution of the Imperial scheme, as it appears to me to be one of the most vital importance, and which should form a characteristic feature of any like scheme instituted elsewhere in the Empire. Such a work requires the authority and the purse of the nation as a whole behind it, and its direction should undoubtedly be regarded as a proper Government function, in the interest of the whole community.

It was soon found that the work of the Committee of the Privy Council and its Advisory Council required establishment of a special "Department of Scientific and Industrial Research," and the foundation of this department led to the creation of a body corporate, under the name of "The Imperial Trust for the Encouragement of Scientific and Industrial Research," to have control of the expenditure of the fund of one million pounds sterling voted by Parliament for this object, such fund being expected to provide for the work for a period of five or six years. It was ascertained that it would not be possible to develop systematic research in several industries unless the Government were prepared to assist financially for an agreed term of years, but it is expected that the industries, and especially the great staple manufacturing industries of Great Britain, will bear a considerable share of the large expenditure involved, and some of them might find themselves able to carry on the work without Government assistance once it was well started. To this end the Department of Research is encouraging and inviting the formation among suitable industries and groups of industries of Association for Research, established under the Companies Act, but limited by guarantees and debarred from taking any profits. These Associations of manufacturers and persons concerned in the various industries are a very vital and valuable part of the British scheme, and should be very effective in providing not only funds for research, but also the best of opportunities and facilities for investigators, and the best means of bringing the latter into most intimate connection with the practical problems of manufactures. Associations for research are being, or have been formed in the cotton industry, among the woollen and worsted manufacturers, in the Scottish shale oil industry, and among photographic manufacturers, while many other industries are reported to be considering the formation of like associations, primarily for the purpose of working out problems arising in the practice of their particular industries.

In another direction where national control is requisite, the Department of Research is acting somewhat more directly, having

taken over the control and responsibility of the National Physical Laboratory from the Royal Society, thus relieving this body from much financial anxiety. The Executive Committee of the Royal Society, however, continues to have the management of the work of the Laboratory as a committee under the department. It is believed that this course "will help to bring fundamental research into closer and more continuous relation with the investigations into processes and products which must occupy so large a part of the attention of the works research laboratory."

A Special Fuel Research Board has been constituted to deal with the problem of Fuel Economy, and a grant of £1,000 a year for five years with £750 special grant for apparatus has been made to the Department of Technical Optics recently established at the Imperial College of Science and Technology, which on its part is providing laboratory accommodation and a grant of £2,000 for equipment. This department is also getting generous support from the Board of Education, London County Council, and the Optical Industry.

Up to the end of the financial year 1916-17 the Department of Research had considered and approved recommendations in aid of forty-four scientific investigations of industrial importance.

The report of the Advisory Council for the same year urges the vital need of research at the Universities, especially in pure science, and their belief that co-operation is necessary between capital, management, science, and labour "as the best means of financing and directing the extended laboratory investigations and large-scale experimentation required for industrial research." They have addressed themselves in the main to the organisation of industrial research, feeling the "paramount importance of arousing and securing the interest of manufacturers in the application of science to industry," bearing in mind at the same time Sir Joseph Thomson's aphorism that "pure science is the seed of applied science."

In Australia a like movement to that in Great Britain was soon set on foot, but for some time it was confined mainly to making a survey of the field of work to be entered upon, in order to see on what lines it would be best to make the attack. For this purpose an Advisory Council was appointed in March, 1916, and now comprises 35 members representing all the States of the Commonwealth of Australia. It was apparently intended to be a more or less temporary body, to prepare the way for a permanent Institute of Science and Industry, the establishment of which is now expected to be completed very shortly.

The chief functions of the Advisory Council are (1) "to consider and initiate scientific researches in connection with or for the

production of primary or secondary industries in the Commonwealth, and (2) the collection of industrial scientific information and the formation of a bureau for its dissemination amongst those engaged in industry."

Owing to the difficulty of getting the whole Council to meet together, general meetings of the whole body have been few, and the work of the Council is carried out mainly by an Executive Committee sitting in Melbourne, and State Committees meeting in each State of the Commonwealth. With the intention of preserving the necessary close touch between the Executive Committee and the Government, the Prime Minister, or in his absence the Vice-President of the Executive Council, is chairman of the Executive Committee, but it is to be regretted that stress of public business necessarily makes it somewhat uncommon for either to take an active part in the operations of the Committee. The arrangement therefore does not seem to promise quite such complete mutual understanding between the Federal Government and the Committee as is provided by the British system of direct control of the Department of Scientific and Industrial Research by a Committee of the Privy Council. It is expected, however, that in the proposals shortly to be laid before the Federal Parliament, this will be remedied by forming a Department of Science and Industry in close connection with a wider one of Commerce and Industry.

The Chairmen of the State Committees become *ex officio* members of the Executive Committee, and by receiving minutes of its proceedings and copies of all information supplied to it are enabled to keep in touch with the work of the central body and form a link between it and the State Committees.

The State Committees are formed of all the members of the Advisory Council resident in the State, together with associate members representative of particular branches of science and industry. The associate members are usually nominated by the State Committees, and appointed by the Federal Government, but are not members of the Advisory Council. The State Committees consider matters arising within and especially affecting their own States, and report thereon to the Executive Council, which then decides as to any executive action and authorises such expenditure as may seem to it to be necessary.

In order to enlist the co-operation of specialists in any subject under consideration, Special Committees may also be appointed by the Executive to study and report upon special problems. These should be the main working committees of persons with special knowledge of the matters taken up. They may be appointed directly by the Executive Committee of their own initiative, or more usually are invited by the State Committees to deal with par-

ticular propositions and appointed by the Executive Committee on their recommendation.

Up to 30th June, 1917, there had been appointed 20 special committees, and grants had been authorised to them for necessary expenses of £3,435. The list of these committees will give a good idea of the nature of the subjects with which they deal:—

1. Chemicals.
2. Ferro-alloys.
3. Standardisation of design of scientific apparatus.
4. Mode of occurrence of gold in quartz.
5. Tick pest.
6. Alunite.
7. Yeast and bread making.
8. Nodule disease in cattle.
9. Marine Biological Economics of Tropical Australia.
10. Damage by insects to grain in store.
11. Electrical sterilisation of milk.
12. Tanning properties of Queensland mangroves.
13. Tanning properties of red gum in Western Australia.
14. Means of transmission of worm nodule parasite.
15. Control of sparrow pest.
16. Alcohol fuel and engines.
17. Classification of imports of chemicals.
18. Tanning methods of New South Wales.
19. Posidonia fibre.
20. Grass-tree.

In a later list up to April, 1918, the number of Special Committees has been increased to 27, and some of them of which the work is of a permanent or prolonged nature have been established as standing committees.

From this list of subjects it will be seen at once that it has been specially intended to take up subjects of particularly Australian interest and value, and that primary production and industries immediately springing therefrom have had more attention than the more advanced industrial processes. Many of the problems taken up, such as those relating to pests, require much co-operation of practical producers, scientific investigators, and Government authority.

One great aim of all Special Committees should be to find out and enlist the active sympathy and co-operation of all active workers in the particular field to be investigated, so as to get combined effort with the minimum of duplication and overlapping. Massed attack is the object, not individual sniping.

The investigations on cattle-tick pest and beef-nodule worm, eradication of prickly pear, cotton growing, tanning materials,

power alcohol, sources of potash, pottery materials, and several other matters, have already resulted in the publication of bulletins, but these mostly are of a more or less preliminary character, giving statements of the position as regards each problem and narrating the steps taken already and regarded as necessary to attack it, but in most instances still leaving the main bulk of the experimental and investigational work to be done by people able to devote their whole time and energies to it in properly equipped laboratories and also on a practical working scale outside.

The Advisory Council has as one of its functions the establishment of a bureau for the collection of industrial scientific information and its dissemination, and has been preparing a catalogue of scientific periodicals available in Australia and numerous abstracts of information on a large number of subjects about which such is desired by Special Committees and other investigators.

It will be seen that the Australian movement is not yet quite so far advanced as that in Great Britain, having had to spend more time over arrangement of preliminary work, and not being in a strong financial position. In Great Britain, a large manufacturing country, the investigations immediately required relate very largely to improvements in methods and processes of established industries, and have the support of many interested manufacturers, willing to assist with money and workshop facilities. In Australia the problems are considerably different, as they relate more particularly to development and improvement of the primary industries, and foundation upon them of derived secondary ones, many of which are at present quite new to this country. Investigations of opportunities for starting industries yet untried here, but well known elsewhere, are as important as those dealing with new processes and discoveries. We have not the benefit, as in Great Britain, of assistance from a large body of wealthy and interested manufacturers ready to assist in such investigations, and in consequence a much larger share of the financial burden of the work falls upon the community as a whole, through its Government. Even in Great Britain it is found that there are many necessary investigations of which the immediate bearing upon their interests is not so apparent as to claim support from manufacturers, and which have therefore to be supported from the public funds. The Advisory Committee refer to some of these in their 1916-17 report, as fields of research of wide and general importance affecting almost all industries and people and therefore best to be dealt with directly by the Department of Research, and financed from its funds.

The scheme of action outlined by the Prime Minister of the Commonwealth at a conference in Melbourne at end of February last and likely to be adopted more or less completely by Parliament very shortly, contemplates the formation of a Department of Com-

merce and Industry, under a Minister for Commerce and Industry, which will organise commerce and industry generally, so far as it can. Industrial Associations formed by the producers in each industry or group of allied industries will form the units of the scheme of organisation within the Commonwealth. Each association will have its council, dealing with the conditions of the particular industry, and representatives from these councils will form a General Council of Science and Industry. "The functions of the general council will be both advisory and executory. It will co-ordinate the activities of the various associations, give the support of its authority and influence to proposals put forward by them for developing trade, opening up new opportunities, improving methods of production, securing financial assistance, protecting local interests, recommending necessary legislation—for example, tariff or bonus—or whatever may be deemed desirable for the protection and expansion of industry. Just as the association will be the mouthpiece and executive of an individual industry, so the general council will be the mouthpiece and representative of commerce and industry in general. . . . The Government proposes to place the Science Bureau upon a permanent basis, appoint first-class men of high qualifications in charge, and give it such financial backing as is necessary to ensure its success. The Science Bureau will be an integral part of the scheme of organisation. It will be in direct touch with the Department of Commerce and Industry and with the General Council and various associations formed under the scheme. Through it we will link up the technical schools and colleges, and through them the Universities and general schools." The appointments have been recently announced of a Director of Commerce and Industry and a Director of Science and Industry under this scheme.

Up to the present time the work under the Advisory Council of Science and Industry has been mainly carried on by the voluntary services of the members of the various committees formed under it, although salaried investigators have been employed in a few instances. This system has some great merits and some very serious weaknesses, the principal merit being the calling out of the best voluntary services of a great number of the scientific workers who are always ready to give of their best for the public good, and who will do so most generously and freely under a voluntary system, while great weaknesses are that such voluntary work is necessarily limited to the time which busy men can spare for it from their everyday absorbing duties, and that there is apt to be a great lack of coordination of effort due to absence of a firm governing authority. Undoubtedly the very high value of the voluntary and unpaid work must be recognised, especially as it often follows lines of investigation which otherwise would probably be passed over, but to carry out systematic series of investigations it is soon obvious that men have to be employed to give their whole time to the work if results

are to be looked for within any reasonable time. The work is of the most absorbing character and requires all the time and energies of the investigators, often requiring continuous observations over periods of time so long as to make serious demands upon their physical strength. On the other hand, any scheme which disregards the help of the voluntary worker and depends entirely upon a salaried staff is apt to become purely a departmental one, and to lose the valuable stimulus of exchange of ideas and suggestions between the salaried men and the voluntary workers. Purely departmental effort is apt to get into grooves, and may very easily get completely out of touch and sympathy with much work being done on more or less parallel lines by independent workers. It seems to me that the usefulness of the Imperial Institute, an organisation primarily intended to take up much the same sort of work as is now to be taken in hand by the Councils of Science and Industry, has suffered very markedly from exaltation of the departmental aspect and losing touch with the body of active outside workers.

The most desirable combination appears to be one in which the paid investigators are to a considerable extent responsible, not merely to their immediate departmental heads, but also to the public opinion of the body of more or less trained workers on the particular matters undertaken. These should have opportunities of ascertaining the nature of the work being done, and should be encouraged to make suggestions, and to carry on additional investigations on their own account. They should have opportunities of discussing the reports of the investigators before these are finally given to the world, and be invited to express their opinions upon the results. In most investigations of the class to be undertaken, the general public is not competent to judge the value of the work done, and has to depend upon the opinion of it formed by a few of its members better qualified to appreciate such work. If these are satisfied with the results obtained, the public in general can follow them with much confidence. There are advantages therefore in a system which ensures that the investigations carried on shall be made under a certain amount of supervision and discussion by committees of persons whose training and interests enable them to understand and appreciate the work done. This would be quite in keeping with the traditional practice of the British people, whose genius has long seized the cardinal principle of entrusting direction of its activities to the most capable persons in each branch of public work, selected by choice of the limited section of the whole people best able to judge in the particular case.

It would appear therefore that the lines of the proposed Commonwealth scheme, aiming to obtain the co-operation of all workers in any branch of industry, are well devised, and preferable to any

proposition which would relegate the volunteer assistants to a place of no importance, quite outside of a purely departmental administration. The advisory councils and committees should be live bodies, with much direct control over the lines of investigation to be followed. Close co-operation in this way of the salaried and unpaid workers will result in very much more general interest being taken in the work being done, and in far more widespread appreciation of it by the general public. It appears to me that much stress should be laid upon this aspect of the matter and every effort made to popularise knowledge of the scientific work done, to interest and obtain the active co-operation of as many voluntary workers as can be got together, and to avoid relying too much upon purely departmental organisations.

In other parts of the Empire very similar action is being taken to that in Australia in formation of organisations for the progress of industry under the guidance of science. New Zealand has formed an Industrial Efficiency Board, a name which suggests a departmental rather than a popularly constituted organisation; Canada has formed a Committee of Council for Scientific and Industrial Research; South Africa and Rhodesia have Scientific and Technical Committees; and the Government of India has directly undertaken a special investigation upon the dyeing of tussore silk. From such little information as I have been able to obtain it would seem that these bodies are mostly proceeding in much the same way as the Australian Advisory Council, first by taking stock of the field of endeavour and then by investigating problems of especial interest to their own people and organising means of combined effort of interested parties to develop industries.

Both in Great Britain and the United States of America much help is being given to the Governments by many of the great scientific and professional societies, such as the Royal Society, the Institution of Mining and Metallurgy, the Institutions of Civil, Mining, Mechanical, and Electrical Engineers, the Chemical Societies, and many others. Indeed it may be said that practically all such bodies have placed their best services at the call of the Governments for any use which may be made of them, and much very useful work has been done by them. They are formed of the specialists in the community in their particular domains who are best able to advise the people as a whole on questions relating to these domains.

Returning to the Australian position, the particular needs of each State are not in all cases satisfied by the steps which have been taken by the Federal Government, and some of the States themselves have undertaken more or less work in aid of the development of their own particular industries. Our own State of Western Australia has formed a Department of Industries under a Minister of Industries, which is striving to institute new industries suitable for

the resources of this State without waiting for the Federal organisations to take action. There is no reason for any clashing of authority or duplication of effort through the State taking such action, as it should be possible for both State and Federal organisations to work quite well and harmoniously together with much mutual advantage. In many industries it will be of very great advantage to have the State authority working in the interests of its own State, as the more general Federal one may not be impressed with the necessity of moving in many matters which the more local State one can see are most important for its own case. Other States also have found it advantageous to use the resources of their public departments and State authority to facilitate development of industries in which such States are particularly interested, and in the great centres many even more local organisations have been formed among the people most concerned, *e.g.*, the Institute of Victorian Industries, and our own small League for the Promotion of Industries. The last-named body is of interest to the present audience because the Royal Society of Western Australia accepted an invitation to become one of the members of it. Its aim is to link together all the more or less public bodies interested in the many various aspects of the development of industries, so as to make use of the services of any persons who can contribute special knowledge towards the solution of any particular project. It is also notable as a local example of the practical difficulty of focussing such energies upon any one immediate object, for no sooner is a suitable industry suggested to be started than the need arises for some person or party to take it up in a commercial manner, and the need of considerable funds becomes at once an urgent one. No progress is possible without a good deal of expenditure. Such a body as this league can suggest openings for industries and investigate many matters of great importance to those starting them, but someone else has then to undertake the actual venture. The greatest usefulness of such a body would really be at a somewhat later stage, when the persons who have undertaken an industry find that they want advice on points in the special provinces of the various societies composing the League, which could then assist them very considerably by investigations and advice. The aims of this League and of Departments of Industry need not necessarily require any new researches or solution of scientific problems, the establishment of quite a humble industry like manufacture of glue or blacking being quite as much within their province as ventures of a more ambitious type. There are numbers of little industries which are very much required, and which ought to be undertaken, which do not require immediately any special help from science.

The little local example of the Society for the Promotion of Industries is more or less typical of the efforts being made throughout the whole field of industrial endeavour which it is the aim of

the greater movement under review to cover. There is an advisory and investigational side to them all, for which the voluntary services of a large body of willing helpers are available, and there is a practical commercial side which necessitates capital and business ability for starting the actual industries. For this latter side both the British and Australian schemes rightly rely very greatly upon the associations of manufacturers and producers to carry projects into practical effect. These comprise the people who understand the business aspect of the matter, and who are able and willing to spend money to start commercial industrial propositions when a sufficient inducement seems to be before them. It is the function of the advisory side to survey the field as thoroughly as possible and get together all the information of use to those actually engaging in the industry and to make investigations to remove difficulties and solve problems. Then when an industry has actually been started, its operators should be able to get the help of the advisory side in coping with the many difficulties which are sure to arise. In this phase of the matter the policy adopted by the Mellon Institute in the United States seems an admirable one to follow. They send advanced students to various industrial factories to learn all they can of the practical working of the business and get a knowledge of its problems. After a time these students return to the Institute for further training and to carry out special researches on the problems encountered in practice, and then go back into the factories to carry on like work there under business conditions. With a like purpose the British Advisory Committee suggests attaching young research workers to the laboratories of various manufacturing works for an agreed length of time, which might be divided into three periods. During the first period the department would pay the salary of the worker, during the second the department would pay half, and during the third the firm would pay the whole. It is expected that in this way the technical direction of industries in time will fall very largely into the hands of men who themselves have had a scientific training, or at least have been accustomed to work in close connection with a scientific staff, and that the influence of scientific methods will thus become more and more increasingly felt throuhgout the industries.

It will be seen that the whole movement has become dominated by its industrial aspect, the great object being to bring the resources of science to bear in assisting industrial development with a view to very immediate results. To a very great extent this is highly desirable, and to many business men it may seem that it is the only side of the question which is worth considering, but there is some reason to be afraid that in the desire for immediate results it may be overlooked that these cannot be obtained without much research work, the objects of which are not intelligible to the uninitiated. The public are apt to expect too much of their scientific advisers

through thinking that they ought to know already all about very many things which still require much investigation, and they are therefore liable to be very impatient at delays of which they do not understand the reasons. The scientific advisers are then told that they are wasting time over things of no value to anybody, and only of scientific interest, the ignorance of the critic of all knowledge of the matter being no bar whatever to his having an ineradicable conceit in his own ability to form a judgment. It is very hard to convince such persons that there are no royal roads to scientific achievement, and that the way to success is through incessant attention to minutiæ of which the importance may not be appreciable at first even to the investigator himself. The importance of research work and progress in pure science must not be allowed to be lost sight of in the desire for immediate utility as a direct outcome of the investigations, and the community must be trained to recognise that much time and money may have to be expended on scientific researches before practical results can be looked for. Some such idea as this appears to have been in the minds of the British Committee of the Privy Council for Scientific and Industrial Research when they concluded their 1916-17 report with expression of a belief that the work of the Advisory Council "will help to achieve that revolution in the attitude of your Majesty's subjects towards scientific thinking, without which no expenditure of money on industrial research, however lavish, will avail." The general public have to be educated to a reasonable appreciation of scientific work and its methods, to have some understanding of its capabilities and its limitations, and to learn that scientific knowledge of the principles underlying industrial operations is just as necessary to industrial operators as is understanding of trigonometry to those of a land surveyor.

In its earlier endeavours the Australian Advisory Council of Science and Industry may appear to some people to have confined its work rather too much to the scientific side of the subjects taken up to the detriment of more practical issues, but closer acquaintance with the work done soon shows that no reproach of this sort is fairly applicable. As scientific men the Council have had a better understanding than most of their critics of the sort of researches necessary before practical issues can emerge from them, and have set about the problems before them on lines which give good promise of ultimate success.

Our survey of the movement under notice has brought out the very general desire for co-ordination of effort and prevention of unnecessary overlapping of investigation. It also raises important practical questions as to the delimitation of the spheres of action of the various bodies which have been organised in order to get the best results. How far, for example, should the Australian re-

searches avoid the subjects taken up by the British investigators, or the State Department's efforts be under control or direction from a Central Commonwealth authority? It seems to me that we must avoid making a fetish of centralisation and co-ordination, and remember the cardinal importance of individual initiative in both scientific investigations and those relating to practical industrial activities. There should be no checking of Australian investigation of timber problems because the same ground is being gone over in Canada, nor should any impediment be placed in the way of West Australian researches into the pottery clays of this State because some other body of workers is engaged with the same subject in New South Wales. The old adage is very true that when one wants a thing well done one must do it oneself, and there are many matters which may appear to be of small concern to a central authority which are highly important to local bodies and persons. If we desire to find a use and a market for, say, Xanthorrhea resin (Blackboy Gum) because the raw material is very plentiful and cheaply obtainable in this State, we are more likely to succeed in doing so if we investigate locally where the importance of the quest is understood than if we send to an authority at, say, the Imperial Institute, to whom it is of little interest whether supplies of material for the British markets come from Western Australia or Winnipeg. His interest naturally is in getting fitting material for the use of British manufacturers wherever he can get it to best advantage, while ours is to get our particular local article brought into notice and use. It is evident that the individual and local efforts for starting particular industries in particular places must in the end be the principal means by which any commercial results are reached, and that the whole systematisation of research should be to the end, not of accumulating knowledge at a central source, but in spreading it so that it finally results in individual performance. The great end should be to make it as easy as possible for the man who begins and carries on an industry to know everything that will help him to work to the best advantage, and to obtain the assistance of the most capable scientific investigators, whether they are near to him or at the other end of the Empire.

Perth, 30th May, 1918.

DECIMALISATION OF THE BRITISH CURRENCY.

(Read 11th September, 1917.)

In a decimal notation every figure represents ten times as much as the one standing to the right of it. In a decimal currency the coins should progress in a like manner, thus: £1, £0·1, £0·01, £0·001.

Existing "decimal" currencies.

The so-called decimal currencies at present existing are none of them made up in that way. They are in the main binary systems. Nearly every coin is twice the value of the one next below (not ten times). Payments made in coins of these systems are, however, recorded in decimals and decimal fractions of one of the coins. The systems of account are therefore decimal, while the actual currencies are not.

The following is a list of the coins in use in the countries composing the "Latin" Monetary Union (France, Italy, Belgium, Switzerland, and Greece), Germany, United States, Russia, and Japan, all of which countries have that system of currency commonly spoken of as decimal. It will be seen that there is no single instance of a coin which is ten times as valuable as the one next below it, as there should be in every case if the currency were as truly decimal as is the method of recording amounts:—

LATIN MONETARY UNION (ALSO SPAIN).

		Ratio.
Bronze	Centime	...
	2 Centimes	2
	5 „	2½
	10 „	2
Silver	20 „	2
	50 „	2½
	FRANC	2
	2 Francs	2
Gold	5 „	2½
	10 „	2
	20 „	2
	50 „	2½
	100 „	2

UNITED STATES.

		Ratio.
Bronze	Cent	...
Nickel	5 Cents	5*
Silver	Dime (10 cents)	2
	Quarter (25 cents)	2½
	Half (50 cents)	2
	DOLLAR	2
Gold	2½ Dollars	2½
	5 „	2
	10 „	2
	20 „	2

* In the United States Mint Report for 1916, page 8, the Director calls attention to the want of a 2½ cent piece. Many articles are sold at 5 cents because there is no other small coin but the one cent piece.

GERMANY.

		Ratio.
Bronze	Pfennig	...
	2 Pfennige	2
Nickel	5 "	$2\frac{1}{2}$
	10 "	2
Silver	50 "	5
	Mark	2
	2 Marks	2
	5 "	$2\frac{1}{2}$
Gold	5 "	...
	10 "	2
	20 "	2

RUSSIA.

		Ratio.
Silver	5 Kopecks	...
	10 "	2
	15 "	$1\frac{1}{2}$
	20 "	$1\frac{1}{3}$
	25 "	$1\frac{1}{4}$
	50 "	2
	Rouble	2
Gold	5 Roubles	5
	$7\frac{1}{2}$ "	$1\frac{1}{2}$
	10 "	$1\frac{1}{3}$
	15 "	$1\frac{1}{2}$

JAPAN.

		Ratio.
Copper	1 Rin	...
	$\frac{1}{2}$ Sen	5
	1 "	2
	2 "	2
Nickel	5 "	$2\frac{1}{2}$
Silver	5 "	...
	10 "	2
	20 "	2
	50 "	$2\frac{1}{2}$
	Yen	2
Gold	5 Yen	5
	10 "	2
	20 "	2

Coins proceeding by decimal gradations would be inconvenient. A British currency consisting of four coins only—

Gold:	Sovereign	£1·000	(£1)
Silver:	Florin	·100	(2s.)
	Cent	·010	(2·4d.)
Bronze:	Mil	·001	(·24d.)

would be intolerable. In all the countries just mentioned, although in each case the unit of value is smaller than the pound sterling, an actual decimal currency has not been attempted. The value of the coins in every instance, except that of Russia, progresses by halves, quarters, or fifths of the next higher figure of the notation used for accounts.

The chief advantage of these systems is the method of accounting, by which fractions of the unit are recorded in the same notation as whole numbers, and arithmetical calculations thus simplified.

The decimal system of recording values appears to be most convenient when used in conjunction with the metric system of weights and measures. The two naturally go together, and in view of the widespread use of both systems, there is some ground for considering that it would be wise for Great Britain to adopt them. The change, however, would not be entirely advantageous.

Metric System.

The weakness of the metric system of weights and measures is that, while it accords with the decimal notation used for numbers, it does not accord with the natural way in which men always have divided, and always will divide, measure, and weigh the articles they have to deal with. No man who has to divide any article into small portions would ever naturally think of cutting it into fifths or tenths. Indeed he would find it a difficult thing to do. He would instinctively divide into halves, and then each half again into halves, obtaining quarters, eighths, sixteenths, thirty-seconds, etc.

It will be seen, therefore, that there is a fundamental difficulty due to the fact that the natural way to count (based originally on counting by the fingers) is by tens, and the natural way to divide is into fourths, eighths, etc. If men had been furnished with four fingers instead of five, then perhaps counting would have been done by eights, and the difficulty which has now to be dealt with would never have arisen.

It is obviously impossible to abandon the decimal method of counting. The only questions to be settled are what are the best ways of reckoning weights, measures, and values. British weights and measures are somewhat complicated, although in the main they are more suitable for dealing with division into fourths, eighths, etc., than is the metric system. That system has, however, already been so widely adopted that the only practical choice seems to be between it and the existing tables. Advocates of the compulsory introduction of the metric system are apt to minimise the trouble and expense which it would involve. The trade of the British Empire and of the United States would be disturbed for a long time, and loss, running possibly into millions of pounds, would be incurred in order to arrive at uniformity with the methods employed by nations which have not as much trade as these two great English-speaking countries.

Referring to the proposed compulsory use of the metric system the "Engineering and Mining Journal" of New York speaks of it as a threatened calamity of the first order. It adds that it would lead to changes of the thousands of standards of materials and all sorts of units upon which American industry is based. Manufacturers would be confronted by the necessity of changing gauges, patterns, etc., at costs running to 1,000,000 dollars even in individual

cases. Engineers would lose the old factors and data of work, materials, costs, etc., which from long experience have accumulated in their minds. An *American Institute of Weights and Measures* has been formed, the objects of which are the following: "*The maintenance and improvement of our present (English) system of weights and measures, for the good of our commerce and industry and the well-being of our country. The education of the people with respect to the importance of our weights and measures, through the dissemination of correct information with respect to them, and to the danger inherent to changes to our basic standards of measurement. The improvement of old and the development of additional standards as they may be needed by reason of new conditions in commerce, industry, science, and engineering. The promotion of wise legislation for the conservation of our basic (English) units of weights and measures, and opposition to hasty and ill-considered legislation involving changes from our fundamental (English) standards.*" *

Drawbacks to decimal fractions.

It will be found that persons using decimal weights and measures constantly resort to little devices by which they get away from the use of fractions. When the metre is used by engineers for measuring machinery, a length of, say, 2·385 metres is nearly always recorded as 2385 mm., although the millimetre can hardly be considered a suitable unit for such a measurement. In the bullion trade, and in the Mints, pure gold or silver is represented by unity, but the clumsiness of speaking of all metal below purity as ·555, ·916, ·650, etc., etc., is such that in practice pure gold is called 1000 and standard gold $916 \cdot \dot{6}$, and thus this decimal system of recording fineness is mostly referred to as the millesimal system. Superior as this system undoubtedly is to the old scale of carats and grains, it is unfortunate that when used to indicate the fineness of standard gold, it exemplifies the most serious drawback to the use of decimals, viz., the recurring fraction. Standard gold contains eleven twelfths of pure metal. Under the old system it was shown as 22 carat (*i.e.* 22/24ths). This was a simple, accurate, and easily understood statement. By the decimal system it is recorded as $\cdot 91\dot{6}$, which does not convey such a clear idea, and is not quite accurate. Moreover, when used in calculation this recurring fraction involves more work, and yet can never give completely accurate results.

In calculations in which the figure representing the fineness of standard gold is concerned, time is saved and accuracy attained by abandoning the use of the incomplete decimal fraction in favour of the accurate vulgar fraction. If, for instance, it is required to

* "Engineering," London, 16th March, 1917, page 248.

find out how many ounces of sovereigns would be equivalent to 9189·95 ounces of fine gold, the result is promptly and correctly attained by adding one-eleventh to the weight, thus:

9189·95—fine gold
835·45
10025·40—standard gold

The figure 835·45 would also represent the weight of the alloying metal which would be present in a mass of 10,025·40 ounces of sovereigns. To a person knowing only that standard gold was $\cdot 91\dot{6}$ fine, and not realising that that figure was the equivalent of 11/12ths (as he probably would not if decimals were universally employed), the calculation would be $9189\cdot 95 \div \cdot 91\dot{6}$. Before division by $\cdot 91\dot{6}$ was begun it would be necessary to decide at what point the last 6 should be taken as 7. Taking it as ·916667 the result would be 10,025·39 +, a figure which is not quite accurate. In every instance of a recurring decimal fraction lack of accuracy is unavoidable.

The advocates of the universal use of decimals usually pass lightly over the fact that simple fractions such as thirds, sixths, sevenths, and twelfths cannot be accurately expressed. The words one seventh convey a clear and simple idea, but the row of figures ·142857 repeating does not. The main advantage of decimal fractions is the reduction of quantities to a common denominator; simplifying calculations. The main advantage of vulgar fractions is the facility they offer for reduction to lowest terms, and therefore to terms most easy to comprehend.

The drawbacks to the metric system are obvious, and cannot be overcome. Its advantages, however, are also great. Whether its use should be enforced in British dominions is a matter that should not be settled without very wide investigation into its probable effects. If it should be adopted it would be desirable to introduce a decimal currency as well. British weights and measures are not inconvenient in themselves, or, at any rate, their intrinsic drawbacks are not more obvious than those of the metric system, which necessitates the division of objects into the inconvenient fractions, fifths and tenths, and does not provide for dealing with other fractions the use of which cannot always be avoided, viz. thirds, sixths, sevenths, and twelfths.

It may, however, be found desirable, as in the cases of the United States and Canada, to use a decimal money of account while leaving the weights and measures as they are.

Should it be decided to adopt a decimal money of account, it will be necessary to settle which of the various possible methods is the one which has the most to recommend it.

Pound and Mil.

If the pound be taken as the unit of account, it will be necessary to alter the names of the coins below the value of a shilling, dividing that coin into 50 mils (instead of 48 farthings), and introducing a new penny of five of these smaller farthings (mils) instead of four. The present penny could not be retained, as it would have to be shown in accounts as £0·00416, an entry so clumsy as to be out of the question.

The scale of this *pound and mil* scheme would be as follows:—

	Coins.		Entries in Accounts. £
Gold ...	Sovereign	(1,000 mils)	1·000
	Half-sovereign ...	(500 ,,)	·500
Silver ...	Five Shillings ...	(250 ,,)	·250
	Half-crown ...	(125 ,,)	·125
	Florin	(100 ,,)	·100
	Shilling	(50 ,,)	·050
	25-Mils	(= the old sixpence) ...	·025
	12½ ,, ...	(= the old threepence) ...	·0125
	10 ,, ...	(= 2·4 pence)	·010
Bronze ...	5 ,, ...	(= 1·2 penny)	·005
	2½ ,, ...	(= 1·2 halfpenny	·0025
	Mil	(= ·96 of the old farthing ...	·001

The only coins which would be changed in actual value would be the penny, halfpenny and farthing, which would be replaced by the new penny (5 mils) of the value of $1\frac{1}{5}$d., and the new half-penny ($2\frac{1}{2}$ mils) of the value of three-fifths of a penny, and the new farthing equal to ·96 of the old one. The ten mil piece would in time probably take the place of the threepence. So far as the coins are concerned, therefore, this scheme could be introduced with but little interference with the existing state of things. Accounting, however, would present difficulties. A system by which the familiar sum of 3d. had to be shown as £0·0125, and a (new) penny as £0·005, would be inconvenient to all, and incomprehensible to many. It is one which it is safe to say the British public would not be likely to accept.

Florin and Cent.

To avoid the difficulty of recording all amounts less than £1 by means of decimal fractions, it has often been suggested that the florin, itself the tenth of a pound, should be adopted as the money of account. This would have the advantage that the figures in the tens and hundreds columns of integers would stand for units and tens of pounds. By leaving a space between the column for the units and tens, the figures representing pounds would stand out clearly, and there would practically be three divisions showing pounds, florins, and cents ($2\frac{2}{5}$d.) in place of the three now used for £ s. d. It would, however, probably be more confusing to have figures in what used to be the shillings column standing for florins,

and those in the old pence column for 2⅖d., than to adopt a more completely unfamiliar-looking system.

The outstanding objection to the florin and cent scheme is that people would have to set about learning to think of values in unfamiliar terms. This is not an easy matter. I have been assured by Americans in England that until they have mentally converted our prices into equivalents in dollars it is difficult for them to feel sure as to what they really mean. Similarly British people are vague in their apprehension of the value of prices in francs, dollars, or other foreign units. They instinctively proceed to convert them into equivalents in the familiar sterling terms in order to make no mistake. With the majority of men the apprehension of values is indissolubly bound up with the terms of the unit familiar to them in childhood and youth. If therefore the change to a decimal notation can be attained without the introduction of an unfamiliar unit, much will have been gained.

The scale of the *florin and cent* scheme would be as follows:—

	Coins.		Entries in Accounts. Florins.
Gold ...	Sovereign ...	... ...	10·00
	Half-sovereign	... ...	5·00
Silver ...	Florin ...	... (Of 100 cents)	1·0
	Shilling ...	... (Of 50 cents)	·50
	25 cents ...	... (= the old sixpence) ...	·25
	20 „ ...	... (= 4·8 of the old pence) ...	·20
	10 „ ...	... (= 2·4 „ „) ...	·10
Bronze ...	5 „ ...	... (= 1·2 „ „) ...	·05
	4 „ ...	... (= ·96 „ „) ...	·04
	2 „ ...	... (= ·48 „ „) ...	·02
	Cent ...	... (= ·24 „ „) ...	·01

It will be seen that, as in the case of the pound and mil, there would be a coin of the value of 1⅕ of a penny of the existing currency, but by the interpolation of a coin of four cents a nearer approximation to the value of the old penny could be obtained, viz. ·96d. The sixpence would have to bear a new name—25 cents—while the six coins below the sixpence would bear unfamiliar names and also be of new values. This would necessitate alterations in the prices of all small articles, and result in considerable inconvenience and possible loss, particularly to those least able to bear it.

Shilling and Cent.

The sovereign has now been in use for a hundred years, and has obtained such a stable position in public regard that it would be unwise either to do away with it or alter it in any way. It could, however, be retained as the standard of value and the chief medium of exchange, without also being used as the money of account. Even at the present time, in the case of sums under £5,

business men have a habit of speaking and accounting in shillings instead of pounds. Prices are quoted as 30s., 55s., 66s., etc., instead of £1 10s., £2 15s., and £3 6s., etc. It would not be so very difficult to extend this existing system, and to record all values in shillings and decimals of a shilling. This would not be convenient for dealing with large sums. It is not, however, possible to select a unit equally suited for recording small as well as large amounts. The experience of other countries seems to show that it is more important to consider the convenience of the whole of the people who must always be conducting small transactions, rather than those few who, in addition to their personal retail dealings, have also to do with large sums in the prosecution of their trade or profession.

The unit of account in France, Belgium, Italy, Switzerland, Greece, and Spain is equal in value to 9·52 pence, in Germany to 11·47d., in Norway, Sweden, and Denmark to 13·215d., in Holland to 19.82d., and in Austria-Hungary to 10d.

The extension of the shilling from the position of an occasional unit of account to that of a universal one would place Great Britain more into line with Continental countries, and it would impose no heavier burden on persons dealing with large amounts than is at present borne in other important countries. All values would have to be recorded in shillings and decimal fractions of a shilling. A new penny, the tenth instead of the twelfth of a shilling, would have to be introduced, exactly as it would if the pound and mil system were adopted. In accounts, however, this new penny would appear as 0·1, instead of 0·005. The advantage is obvious. The first figure to the right of those standing for shillings would, as at present, indicate pence (that is the new pence of $1\frac{1}{5}$d. in value). The new halfpenny would be shown as 5 in the next place. As, however, amounts less than halfpence are but seldom required, no harm would be done if conservatively minded tradesmen continued to record halfpence by the old sign $\frac{1}{2}$. The public would thus be confronted with very little alteration in the appearance of accounts of retail transactions.

A slight difficulty occurs regarding the names to be given to the new half and quarter shillings. If it were not for the fact that there are already two coins in circulation of precisely the same value, known as the sixpence and threepence, it would be natural and obvious to call them fivepence and twopence halfpenny. In the transition period, however, there would then be two coins of the same value circulating side by side, one of which would be called a sixpence of the old currency, and the other a fivepence of the new. A simple solution of this difficulty is to divide the shilling into 100 cents; the new half-shilling could then be called 50 cents, and the new quarter shilling 25 cents. The penny would be ten cents, and the halfpenny five cents. The chief objection to

this is that it would add one more to the large number of cents of various values already in existence. It would perhaps be better simply to call these pieces Halves and Quarters. The scale of the *shilling and cent* scheme would be as follows:—

	Coins.		Entries in Accounts. Shillings.
Gold ...	Sovereign ...	... ...	20·00
	Half-sovereign	... ...	10·00
Silver ...	Crown ...	... ...	5·00
	Half-crown	... ...	2·50
	Florin ...	... ...	2·00
	Shilling ...	... (Of 100 Cents)	1·00
	Half ...	... (Or 50 Cents) = Sixpence ...	·50
	Quarter ...	... (Or 25 Cents) = Threepence...	·25
Bronze ...	Ten Cents ...	... = $1\frac{1}{5}$ of the old penny ...	·10
	Five Cents	... = $1\frac{1}{5}$ of the old halfpenny ...	·05
	Cent ...	... = ·96 of the farthing ...	·01

The only coins to be altered in value would be the penny, half-penny, and farthing. There would be no new coins.

A decimal money of account cannot be introduced without some alterations and inconvenience. The shilling and cent scheme seems to present the line of least resistance in this respect. The only burden it would involve, that of using more figures when recording large amounts, would fall mainly upon those institutions and individuals best able to bear it. A small incidental advantage would be that the number of figures required to represent such enormous amounts as those of the national debts of the countries now at war would be roughly the same in England as on the Continent, and comparison, when required, would thus be simplified. As such large figures do not easily convey a clear idea, a further special unit of 100 shillings (£5) might be introduced. This could be indicated simply by leaving a space between the column for tens and hundreds, the figures to the left of which could then be read as so many "fivers" or "quintans," or whatever name might be selected for this special unit for large amounts.

An objection has often been raised in the past both to the pound and mil and to the shilling and cent schemes on the ground that the increase in the value of the penny would cause serious loss to the community. At the present time, when war has caused prices to rise so enormously, this does not strike the mind as a very serious matter. If, when peace is re-established, it is found possible to reduce prices to a level of only one fifth more than they were before the war, then most people will be agreeably surprised.

There is no subject upon which men's minds are more conservative and suspicious of change than the currency. To obtain popular approval, a new system, however beneficial, must involve as few alterations in familiar names and standards as possible. For this reason the three foregoing schemes, each of which takes for the

money of account an amount represented by a familiar existing coin, have a much better chance of success than any scheme in which a new unit of value would have to be used.

Schemes involving alteration of the standard of value.

The Royal Decimal Commission of 1859 reported that "a coinage which necessarily involves the disturbance of the pound sterling would in the present state of public opinion be unadvisable and, in fact, impracticable." At that time the sovereign had only been in existence for 42 years. It has now been the standard of value, the chief gold coin, and the principal money of account for 100 years. About 1,000 millions of these coins have been coined and issued. Public objection to any interference with it would probably be greater now than ever, while the actual inconvenience which any change would cause would be more widespread than it would have been 58 years ago.

Several proposals involving the abandonment of the sovereign, or an alteration in the amount of gold selected to bear that name, have been suggested.

Gold piece of 25 *francs.*

A Royal Commission sat in 1868 to consider the subject of an international coinage, particularly with regard to the recommendation of a Conference held at Paris which had suggested an international coinage on the basis of—

1. The adoption of the single gold standard.
2. The adoption of 9/10ths as the proportion of fine gold in the coins.
3. That all gold coins hereafter struck in any of the countries which are parties to the Convention should be either of the value of five francs or multiples of that sum.
4. That a gold coin of the value of 25 francs should be struck by such countries as prefer it and be admitted as an international coin.

The Royal Commissioners pointed out that "the reduction of the value of the pound" (that is to say to 19s. 10d. the value of the gold in a 25-franc piece) "would disturb all existing obligations and would cause many and serious difficulties," and they concluded their report adversely to the proposal to substitute a 25-franc piece for the sovereign.

Gold Dollar.

Canada does not, and cannot, because of her proximity to the United States, use the British currency system, and it would be desirable, if possible, to adopt some plan by which both the sovereign (containing 113·0016 grains of pure gold) and the dollar

(containing 23·22 grains of pure gold) would be able to take a place. In the British halfpenny and the United States cent there is practical identity, the halfpenny passing for ·2354 of a grain of pure gold and the cent for ·2322 of a grain. It has been suggested that a system might be adopted beginning with the halfpenny or cent and having pieces of 5, 10, 25, and 50 cents, a four shilling piece (or dollar) of 100 cents, and a new sovereign, or five dollar piece, of the value of 20/6·5685d. of the present currency. This proposal, which has been called the *Empire coinage,** would provide coins as follows:—

	Coins.		Value in Sterling	Value in Dollars.
Gold	Sovereign	(10 florins)	20s. 6·6d.	5
	Half-sovereign	(5 florins)	10s. 3·3d.	2½
Silver	Double-florin	(2 florins)	4s. 1·32d.	1
	Florin	(100 mils)	2s. 0·66d.	·50 cents
	Half-florin	(50 „)	1s. 0·33d.	·25 „
	Florin	(25 „)	6·165d.	·12½ „
Nickel	Brit. Dime	(10 „)	2·466d.	·5 „
	Half-dime	(5 „)	1·233d.	·2½ „
Bronze	Penny	(4 „)	·9864d.	·2 „
	Half-penny	(2 „)	·4932d.	·1 „
	Farthing	(1 „)	·2466d.	·½ „

* See London "Economist," 21st April, 1917, p. 701.

This system arrives at uniformity with the American dollar by effecting some alteration in the value of every British coin now in use. It would in fact be nothing but a wholesale adoption of the American system disguised by calling a cent a halfpenny, a 2 cent piece a penny, a 50 cent piece a florin, and the dollar a double florin.

If such a scheme were adopted there would be, during the period of change, which must last several years, two sorts of coins called halfpence, pence, florins, double florins, sovereigns, and half-sovereigns circulating side by side, each of slightly different value. Confusion, and opportunity for mistakes and fraud, would arise. The use of the old familiar names would not alter the fact that the new currency would be the American currency intact, except that accounts would be kept in the new single florin, or half-dollar, instead of in the new double-florin, or dollar. It would be better to adopt the American currency *en bloc,* with the gold dollar as standard of value, rather than to try to disguise it with a dressing of familiar British terms.

It is most unlikely that the British people would consent to abolish the pound sterling, but if they were willing to do so, it would probably serve more useful ends for the country to enter the "Latin Monetary Union," and to adopt the gold franc as the standard of value. France, Belgium, Italy, Switzerland, and Greece, together with Spain, which has an identical system, have a population

of about 108 millions, living relatively close to Great Britain, as against about the same number of people living in the United States and Canada.

To abandon the ancient British currency, and to set up in its place either the French or the American system, would be a more serious and far-reaching undertaking than that which was reported unfavourably upon by the Royal Commission of 1868, and it would almost certainly be vetoed by public opinion.

Coins unsuitable for certain small payments.

In countries employing a decimal money of account goods are still divided into halves and quarters. When the value is small it is often found that there are no coins capable of being used to make up the amount payable, and the purchaser has to pay slightly more than he should do. Frequently the vendor then tenders his customer some practically worthless article as compensation for the over-payment. In the United States, where the smallest coin is equal to a halfpenny, and the next above it to 2½d., there are many occasions when the available coins do not adequately fulfil the office of a medium of exchange. The following figures show the fractions of a franc, and of an American dollar, which cannot be represented by coins in the case of payments for halves or quarters of goods sold at prices below ninepence:—

FRANCE.

Article at	90	80	75	70	60	50	40	30	centimes
Half	45	40	37·5	35	30	25	20	15	
Quarter	22·5	20	18·75	17·5	15	12·5	10	7·5	

UNITED STATES.

Article at	15	14	13	12	11	10	9	8	7	cents
Half	7·5	7	6·5	6	5·5	5	4·5	8	3·5	
Quarter	3·75	3·5	3·25	3	2·75	2·5	2·25	2	1·75	

ENGLAND.

Article at	9	8	7	6	5	4	3	2	pence
Half	4½	4	3½	3	2½	2	1½	1	
Quarter	2¼	2	1¾	1½	1	1	¾	½	

It will be seen that the existing British coins meet the requirements of every one of these cases, whereas there are *six French* and *twelve American* instances in which the amounts required cannot be made up by means of the coins which are available.

Australian Select Committee on Coinage.

In 1901 a Select Committee was appointed by the Australian Government "to inquire into the desirableness and expediency of the Commonwealth coining gold, silver, and copper coins, and adopting a decimal system of coinage."

In paragraph 11 of the Committee's Report it is stated that the retention of the sovereign as the standard of value is the only basis upon which a decimal coinage proposal would find favour in

Great Britain, and that the adoption of that basis in the Commonwealth would therefore be a movement on the lines likely to be followed by Great Britain. The suggestion to bring the proposed coinage into unison with that of the United States, and thus associate with one of the great decimal systems already in existence, deserved and received attention. It was decided, however, that the objections outweighed the advantages.

The Committee summarised their recommendations as follows:—

"1. That the Commonwealth adopt a decimal system of coinage and money of account.

"2. That the basis of the currency be gold, and expressed in the existing British sovereign.

"3. That the following coins of the existing system be adopted:—

" the sovereign	half-sovereign	two-shilling piece	shilling	sixpence
" 10 florins	5 florins	1 florin	½ florin	¼ florin
" 1,000 cents	500 cents	100 cents	50 cents	25 cents

"4. That a new coin, of the value of 2⅖d. of the existing currency, be coined in some mixed metal and made current as ten cents (one-tenth of a florin).

"5. That bronze coins of the value of—

1	1000th	1	500th	1	250th of a sovereign
1	100th	1	50th	1	25th of a florin

to be known as 1 cent, 2 cents, and 4 cents respectively, be coined to take the place of the existing bronze coinage."

The Committee's decision to recommend the retention of the sovereign as the standard of value is clear, but they did not state what unit it was proposed to adopt for the decimalised money of account. If it was intended to have all values recorded in pounds and decimals of a pound, then the difficulty to which I have already referred would arise, namely, that the small amounts constantly used in retail trade would be represented by awkward decimal fractions:—

A Shilling would be shown as	£0·05
Sixpence " "	0·025
Threepence " "	0·0125
Ten cents " "	0·01
4 cents " "	0·004
2 cents " "	0·002
1 cent " "	0·001

The word cent, however, should be used for the hundredth part of the money of account, but the Committee proposed that name for the thousandth part. This would seem to indicate that it was their intention to recommend that accounts be kept in florins. In that case the decimal fractions representing small amounts would be reduced by one figure, and to that extent be somewhat simpler

to deal with, though it would still be difficult to get used to keeping accounts in which three adjacent columns of figures no longer stood for pounds, shillings and pence, but for florins (2s.), 10 cents ($2\frac{2}{5}$d.), and cents (approximately farthings), and by which the nearest thing to the old familiar penny would have to be shown as 0.04 of a florin.

The Australian Government hesitated to introduce this system without first knowing what the British Government was likely to do in a similar direction, and the decimalisation of the coinage, both in England and Australia, has not yet been accomplished.

Conclusion.

It will be seen that the decimalisation of the British currency is not a simple matter. In the first place the decimal system itself is by no means a perfect one, and it is not easy to be certain that its undoubted advantages are not equalled by its drawbacks.

Assuming, however, that it has been decided to adopt it, there are several schemes to choose from. It is almost universally admitted that the sovereign must be retained as the standard of value, and also as the chief gold coin. This at once cuts out the possibility of complete agreement with either of the other two great currency systems, the American and that of the Latin Union.

There are three main proposals as to the money of account. The Pound and mil, the Florin and cent, and the Shilling and cent. The adoption of any one of these must involve difficulty, and for a time at least some confusion. The question is: which system can be introduced with the least disturbance?

The outstanding advantage of the Pound and mil scheme is that large sums would be shown in the same way as at present, but its unsuitability for small amounts would be a constant source of difficulty and annoyance.

The Florin and cent scheme would enable pounds to be shown as at present by the simple device of leaving a space between the units and tens in the figures indicating florins. The decimal fractions representing the smaller sums would not be quite so unwieldy as in the former case. The necessity, however, for persons (accustomed to think of values in terms of pounds or shillings) to familiarise themselves with a notation showing all values in florins and tenths and hundredths of a florin constitutes a serious, if not a fatal drawback to this scheme.

The Shilling and cent scheme is by far the best for dealing with the small transactions of daily life, the shilling being already widely used as the money of account when comparatively small sums are dealt with. As a unit of account it would closely approximate to those of all the principal countries of western Europe.

The great drawback to this scheme is that the familiar record of large sums in pounds would disappear, and more figures would have to be used for this purpose than we are now accustomed to.

It is impossible to have a single unit of account which is equally convenient for both large and small sums. The decimal system, however, requires that only one unit of value be used. Either the bankers and dealers in large sums, or the small traders and the public generally, must be inconvenienced. A choice must be made. All the countries which have hitherto adopted a decimal money of account have chosen a small unit. If the British Empire is to follow suit in the matter of recording values by a decimal notation, it also would be wise to follow the same course.

Public usage has firmly established the shilling as a unit of value for amounts under £5. Its extension as the unit for all values could therefore be brought about without much difficulty.

When no possible course is free from some drawback it is not easy justly to assess the value of the advantages and disadvantages of the available alternatives. My own opinion is that the sovereign should in any case be retained as the standard of value, and that there is no occasion to have any other standard gold coin for the Empire. The half-sovereign, which has never been used for international purposes, and is an expensive coin to manufacture and to maintain, should be reduced from its status of a coin of full intrinsic worth to that of a token similar to the silver and bronze coins. I feel some doubt as to the wisdom of introducing a decimal money of account, but if it should be decided to do so, then the shilling should be the unit. Sums of less value than a shilling to be expressed in decimal fractions of a shilling. The tenth part of a shilling to be called a penny. In tradesmen's accounts there would be only two columns of figures, the first showing shillings and the second pence and decimal fractions of a penny. In accounts representing very large amounts hundreds of shillings (£5) could easily be treated as a convenient unit. The use of this special unit would reduce the number of symbols required to record vast sums of money. The coins forming the actual metallic currency would be those which are set out on page 24.

About ¼ natural size.

SCALY-TAILED OPOSSUM

WYULDA SQUAMICAUDATUS, gen. et spec. nov.

From a painting by
G. Pitt Morison.

A NEW SPECIES OF MARSUPIAL OF THE SUB-FAMILY PHALANGERINÆ.

By W. B. Alexander, M.A., Keeper of Biology in the W.A. Museum.

(Read 9th April, 1918.)

The interesting animal represented in the accompanying plate (Plate I.), which is a reproduction of a most accurate painting by Mr. G. Pitt Morison, was received at the Western Australian Museum in the flesh from the Perth Zoo during the writer's absence in Melbourne. Unfortunately, no measurements or observations were made on the fresh specimen. The skin was mounted for exhibition and the skull preserved.

The authorities of the Zoological Gardens stated that it had been presented to that institution by the Hon. Walter Kingsmill, M.L.C., President of the Zoological and Acclimatisation Board, who had received it from Violet Valley Station, via Wyndham.

The specimen is a female, apparently adult, though from the unworn condition of the teeth it is evidently not an old individual, so that it may not be full grown.

The remarkable tail at once indicated that it was a representative of a species new to science, and after careful consideration it seems necessary to create for it a new genus, since, though it is undoubtedly nearly related both to the Cuscuses (*Phalanger*) and the Australian Opossums (*Trichosurus*), it presents certain features characteristic of each of those genera, whilst its tail is unlike that of either.

For this new marsupial the name of *Wyulda squamicaudata* is proposed. The word "wyulda" is the aboriginal name for the common Australian opossum on the Lyons River, N.W. Australia, and should be pronounced as if spelt in English weeoolda. As a vernacular name, Scaly-tailed Opossum is suggested as the most suitable for use in Australia. Those who still refuse to accept the inevitable, and object to the use of the term opossum for any animal not belonging to the family Didelphyidæ, will presumably write of it as the Scaly-tailed Phalanger.*

External characters.

Size comparatively large. Approximate dimensions (measured on the stuffed specimen):—

Head and body—420 mm.
Tail—305 mm.
Hind leg—100 mm.
Hind foot—45 mm.
Ear—26 mm.

* The name bandicoot, originally given to an Indian rodent, is now universally used also for several Australian marsupials. There would seem to be less objection to the use of the name of an American marsupial for an Australian member of the same class.

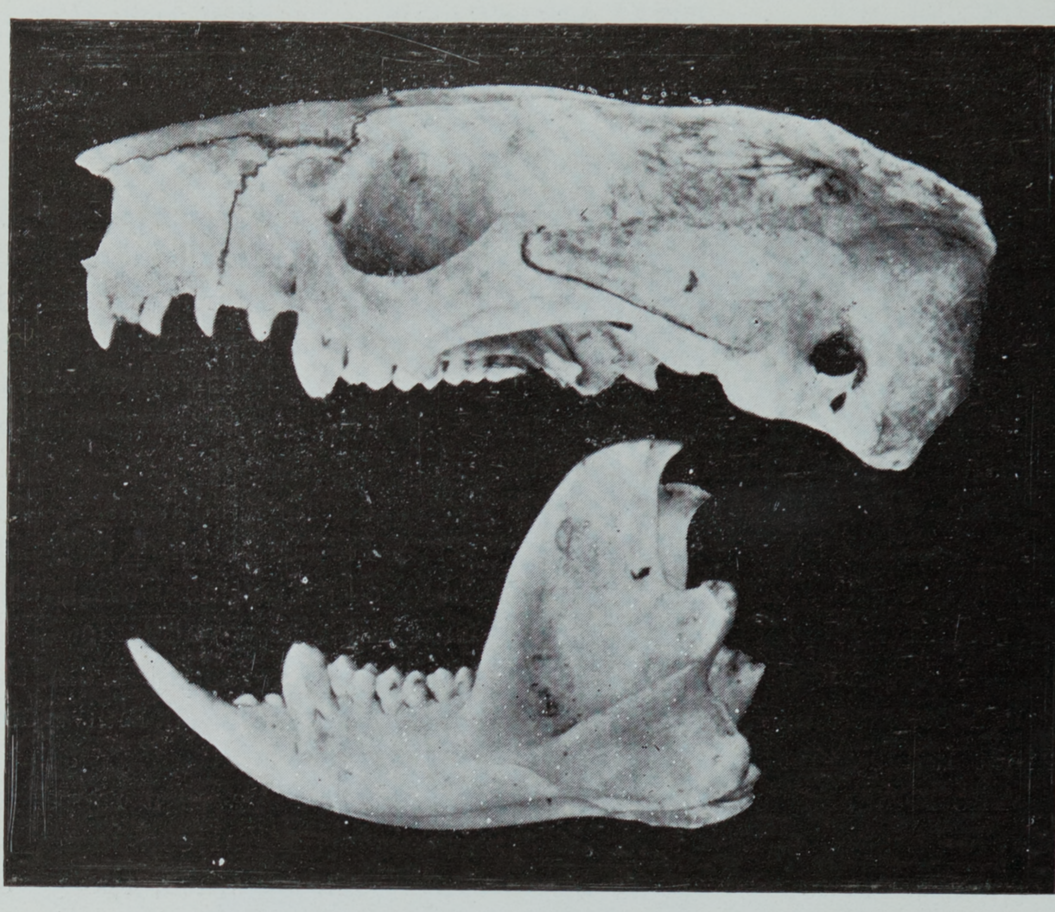

Fig. 1.—Lateral view of skull of *Wyulda squamicaudata*, n. gen. et spec. (nat. size).

Fig. 2.—Dorsal view of skull of *Wyulda squamicaudata*, n. gen. et spec. (nat. size).

Fur close, the hairs not so long or so frizzly as in *Trichosurus vulpecula,* not nearly so woolly as in *Phalanger maculatus* or *P. orientalis.* General colour above grizzled, owing to the fact that the shorter hairs are grey whilst the longer ones have black tips. On the upper surface of the limbs, especially the hind limbs, the fur is more sandy in colour. Throat and under parts yellowish; whitish on the sides. No discolouration on the chest. Hair on toes tawny. Ears smaller in proportion to the size of the animal than in *Trichosurus vulpecula,* but larger than in *Phalanger maculatus,* a little longer than broad, rounded at the tip, with a few hairs inside; externally with a thin covering of hairs. Flanks without a flying membrane. Rhinarium almost naked.

Fore-toes sub-equal, the fourth the longest, followed by 3, 5, 2, and 1. Claws short and stout. Palms and soles naked, the pads large, low, faintly striated, and not nearly so well defined as in *Trichosurus.* Hind foot typically syndactylous.

Tail strongly prehensile, covered with scanty hair for about one-seventh of its length at the proximal end, the remainder destitute of hair but covered throughout its length above and below by small thick, separate scales which do not overlap. These scales are roughly oval in shape, bluntly pointed posteriorly, dark brown on the proximal two-thirds of the scaly portion, yellowish on the distal third. The naked skin on which these scales are set is yellowish throughout.

Cranial characters.

The skull is relatively large for the size of the animal, and is strikingly broad posteriorly owing to the large size of the bullæ. The dimensions are as follows:—

Basal length—73 mm.
Greatest breadth—54 mm.
Nasals, length—29 mm.
„ greatest breadth—14.5 mm.
„ least breadth—10.3 mm.
Constriction, breadth—8.7 mm.
Palate, length—33 mm.
„ breadth outside m2—23 mm.
„ „ inside m2—15.2 mm.
Palatal foramen—5.5 mm.
Basi-cranial axis—24.5 mm.
Basi-facial axis—48.5 mm.
Facial index—198.
Teeth, horizontal length of p4—4.7 mm.
„ length of ms. 1-3—12.5 mm.
„ length of lower i1—12 mm.

The nasals are smoothly convex above and project forward to a level with the anterior point of the premaxillæ, hence the nasal notch is well marked. Interorbital region very narrow, concave

along its centre, its edges sharply ridged. The temporal ridges unite posteriorly and form a sharp crest. The posterior end of the jugal with a sharp ridge on its inner margin, terminating in a distinct point. Anterior palatine foramina running back to the level of the middle of the canines. Posterior palatine vacuities extending back from the middle of m2.

Teeth in several respects intermediate between those of *Trichosurus* and *Phalanger.*

$$\text{Dentition I. } \frac{1.2.3.}{1.\ (2)\ \ (3)} \text{ C. } \frac{1.}{0.} \text{ P. } \frac{1.0.0.4.}{0.0.\ (3).\ 4.} \text{ M. } \frac{1.2.3.4.}{1.2.3.4.}$$

Upper incisors very unequal, approximating in form to those of Phalanger. I1 nearly cylindrical; I2 only half the size of I1 with a narrow base and a broad cutting edge; I3 two-thirds the size of I1, as broad at the base as I2, but the cutting edge not so broad. Canine longer than I3 but not so long as I1, emerging from the bone at the premaxillo-maxillary suture, equidistant from I3 and P1. No sign of a third premolar; P1 functional but not quite as large as the canine; P4 very large, as long as I1, set very obliquely, its anterior end turned outwards, with a ridged cutting-edge. Molars quadricuspid, decreasing regularly in size from before backwards.

Lower anterior incisors large, curving upwards as in *Phalanger orientalis,* proportionately much larger and less flat than in *Trichosurus vulpecula*; I2 small, pointing directly forwards, its tip pressed against the base of I1. Another small tooth, possibly I3, nearly as large as I2, is present on the left-hand side, but doubtfully represented on the right, whilst there is another rudimentary tooth close to the base of P4 on the right-hand side, faintly represented on the left. P4 is obliquely placed and ridged, and with the molars similar in character to the corresponding teeth in the upper jaw.

The relationship of *Wyulda* to the genera *Phalanger* and *Trichosurus* may be summarised as follows:—

Character.	Phalanger.	Wyulda.	Trichosurus.
1. Order of length of toes	4, 3, 5, 2, 1	4, 3, 5, 2, 1	4, 3, 2, 5, 1
2. Pads on soles ...	Ill-defined	Ill-defined	Well-defined
3. Heels	Naked	Hairy	Hairy
4. Tail	Naked at tip	Naked at tip	Hairy to tip
5, Tail (naked part) ...	Smooth or granulated	Scaly	Smooth
. Upper first incisor ...	Cylindrical	Intermediate	Flattened
7. Second incisor ...	Short and spreading	Short and spreading	Long and even
8. Third incisor	Very small	Moderate	Moderate
9. Space between I3 and C	None or small	Considerable	Considerable
10. Size of Canine ...	Large or medium	Fairly small	Small
11. Lower first incisor ...	Long and curving up	Long and curving up	Shorter and flatter

The genus *Phalanger* contains, according to the British Museum Catalogue, five species, though a considerable number of distinct insular species or sub-species have since been described. The genus *Trichosurus* contains only two closely related species. The genera

are separated by the fact that the tail is hairy to the tip in *Trichosurus* but naked at the tip in *Phalanger,* and by differences in the dentition. In the former character *Wyulda* agrees with *Phalanger,* though the tail is more naked than in any species of that genus. The curious scales on the naked part of the tail in *Wyulda* are undoubtedly homologous with the warty prominences met with in some individuals of several species of *Phalanger.* The fact that these warts are so variable in *Phalanger* suggests that they are disappearing and that the ancestral form was probably provided with scales similar to those of *Wyulda.* It seems just possible that the tail of *Wyulda* points to an ancestry from an animal like *Hypsiprymnodon,* that interesting connecting link between the *Macropodidae* and *Phalangeridae,* for in *Hypsiprymnodon* also the tail is covered with scales. These, however, are smooth and contiguous, very unlike those of *Wyulda* superficially.*

In the other feature in which *Trichosurus* differs from *Phalanger,* viz. the dentition, *Wyulda* is decidedly intermediate. In the two species of *Phalanger* whose skulls I have been able to examine, *P. maculatus* and *P. orientalis,* the incisors and canines differ very markedly from the same teeth in *Trichosurus.* In the latter genus the three incisors are not very different in length though the first is longest, and at their cutting edges they are approximately equal in breadth. The canine is usually rather shorter than the third incisor and separated from it by a diastemma as large or larger than that which separates it from the first premolar. In *Phalanger maculatus,* on the other hand, the three incisors are very different in size and form, the first being long and comparatively narrow, the second short but broad at the cutting edge, whilst the third is quite small and is almost crowded out between the second incisor and the canine. The latter is more than twice as long as the second and third premolars, and there is no diastemma between it and the third premolar. Taking these as the two extremes we find that the other species of *Phalanger* and *Wyulda* are all intermediate. In *Phalanger orientalis* the first incisor is little longer than the others. In *P. ornatus,* though the third incisor is small, the canine only touches it at its base. The latter tooth is small. In *P. ursinus* the third incisor is larger than the second and the canine is more or less separated from it and but slightly longer. In *P. celebensis,* though the third incisor is smaller than the second, the canine is separated from it by a distinct diastemma. In this species the canine is about as large as the first incisor and the first premolar. Finally, in *Wyulda* the third incisor is larger than the second, though not as large as the first, and the canine is about half-way between the third incisor and the first premolar and only a little longer than the former.

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* I am indebted to Mr. J. A. Kershaw, Curator of the National Museum, Melbourne, for suggesting a comparison with Hypsiprymnodon, and for allowing me to examine specimens of Phalanger, Trichosurus and Hypsiprymnodon in the collection under his charge.

The differences in dentition alone would seem inadequate grounds on which to separate *Trichosurus* and *Wyulda* from *Phalanger,* in view of the considerable variation in the dentition of that genus. Probably the further differences in the tails will be regarded as sufficient justification for separation however. The separation of *Trichosurus* from *Phalanger* has been universally accepted since the publication of the British Museum Catalogue, and under these circumstances *Wyulda* must also be regarded as generically distinct. The alternative would be to regard these two genera as of subgeneric value only. Subgenera have been proposed for three of the other species of *Phalanger,* and if these were adopted the genus might be divided as follows:—

Genus Phalanger.

Subgenus Phalanger.

P. orientalis. Timor, Southern Moluccas, and New Guinea.
P. breviceps. New Britain and Solomon Islands.
P. ornatus. Northern Moluccas.

Subgenus Ceonyx.

P. ursinus. Celebes.

Subgenus Spilocuscus.

P. maculatus. Austro-Malayan Region from Saleyer (south of Celebes) to N. Queensland.

Subgenus Strigocuscus.

P. celebensis. Celebes.

Subgenus Wyulda.

P. squamicaudatus. N.W. Australia.

Subgenus Trichosurus.

P. vulpecula. Australia (except N. Queensland) and Tasmania.
P. caninus. S.E. Australia and Tasmania.

The writer suggests that some such arrangement as above would indicate the relationships of these forms to one another more satisfactorily than the existing system. In the lack of specimens of most of the species of *Phalanger* in Australian museums, however, it is impossible for him to follow this matter further, and until some worker with access to sufficient material reviews the group on the lines now accepted for northern mammals, the genus *Wyulda* will have to be maintained as distinct from both *Trichosurus* and *Phalanger.*

In conclusion, I desire to express my thanks to Prof. W. J. Dakin, D.Sc., for advice in regard to the examination of the animal; to Mr. J. A. Kershaw, F.E.S., for the loan of specimens for comparison; to Mr. G. Pitt Morison for his excellent coloured picture of the stuffed animal; and to Mr. J. S. Clark and Miss R. Sugden for the photographs of the skull.

THE WEST AUSTRALIAN PITCHER PLANT (*CEPHALOTUS FOLLICULARIS*), AND ITS PHYSIOLOGY.

By W. J. DAKIN, D.Sc., F.L.S., F.Z.S., etc., Professor of Biology, University of W.A.

The pitcher plant of Western Australia is noteworthy as one of the most characteristic endemic plants of one of the most interesting floral areas of Australia. It is the only species of the genus Cephalotus—a genus confined to a small area in south-west Australia. In addition to this, however, it is the only representative of the Cephalotaceæ, an order which does not seem to be closely related to Nepenthes or Sarracenia, although the pitchers are remarkably similar in these different genera. The area in which this plant is found is apparently usually considered smaller than it really is, for one generally hears that Cephalotus is only found near King George's Sound. As a matter of fact it extends westwards probably at least as far as Deep River, and although its range has not been followed to the east it is believed that Labillardiere's specimens came from Esperance Bay. Labillardiere's collections were made in connection with the Expedition of D'Entrecasteaux; the two vessels "La Recherche" and "L'Esperance" visiting the south coast of Western Australia towards the end of 1792.

Whether the plant originated in Western Australia, or is now confined to a tiny fraction of a former larger area, is a question that cannot be discussed in the light of our present knowledge.

Cephalotus is found on swampy land round Albany, growing on peaty soil which is wet in summer and quite sodden in the long wet winter of this region. It is associated in places with the interesting Lycopod—*Phylloglossum drummondii*. The plants are low and quite inconspicuous amongst the reeds—the photographs (Figs. 1, 2, and 3) indicate the usual type of situation. The flower stalks, which grow up in the early months of the year and have a transitory existence, are by far the tallest parts of the plant. Indeed they may reach a height of two or three feet (10-20 centimetres is the height given by Diels & Pritzel, but I am informed that this is unusually low). The flowering period extends between January and March.

Under natural conditions two kinds of leaves are developed, forming a rosette round the stem (at least this is the case in plants growing on the more open ground). The pitchers are modified leaves situated more externally, whilst the ordinary leaves are placed more to the centre. These leaves do not seem so abundant in nature as on our plants grown in the laboratory at Perth, and at the time of correcting proofs of this paper (12th August) all the pitchers have died and withered, whilst the ordinary unmodified leaves appear green and fresh.

Fig. 1.
General view of vegetation where pitcher plants grow, near Albany, W.A.

Fig. 2.
Pitcher plants on ground amongst grasses, etc.

It will be unnecessary to enter into a closely detailed description of the plant here—a very good account may be found in the Proc. Linn. Soc. N.S.W. for 1904 (Hamilton). The full-grown pitchers are about 1-1½ inches in depth, but in many places smaller specimens are the rule. The stalk is attached to the back of the pitcher just below the hinge of the lid. A well-developed flange runs down the front of the pitcher in the middle line, and this bears long stiff hairs. To the right and left of this flange a wing runs from the pitcher rim laterally until it finally merges into the general surface. These wings, like the median flange, also bear stiff white hairs. The very young pitcher, whilst it is only a small swollen body at the end of a long stalk, presents a rather curious appearance owing to the presence of the hairs referred to above. They are relatively so long compared with the size of the young pitcher and so numerous that the young leaf literally bristles with them. The effect is clearly seen in the photograph (Figure 4). The young pitchers are bright green in colour, but as they become older they develop tints of crimson and purple. It is noteworthy that these colours have not been assumed to any extent by our laboratory plants. This may have been due to the lack of insect nutrition (the pitchers have developed and the plants have been grown now for 27 months without insect food), or it may have been the result of other artificial conditions. Further experiments may indicate the factors responsible for the change in tint assumed by the large pitchers in the field. Hamilton states his belief that the ordinary leaves develop in autumn, reach their full maturity in spring, and then gradually go off, whilst the pitchers grow in winter and spring and are fully formed and functional in summer. We have found that the pitchers are apparently functional throughout the year, although much more so in summer; and, so far as our pot plants are concerned, the greatest development of pitchers has taken place in March-April.* This might possibly be a change due to artificial conditions, although it is unlikely, since the plants are being grown in their native soil.

Now, although Cephalotus is not closely related to Nepenthes and is far removed geographically from the home of the latter, there is a remarkable resemblance between the pitchers of these two plants. The same inverted lip is present with the ribs and grooves, and a lid serves the purpose of keeping out rain but is not capable of movement after once opening. Furthermore, on the outer surface of the pitchers we have in both cases a development of lateral wings. On the other hand, there are important differences—the histology of the glands is not the same, and there are morphological divergences. We might regard the pitchers of these two genera, Nepenthes and Cephalotus, as instances of convergent evolu-

* This has now taken place for the second successive year on a plant grown for 27 months in the laboratory.

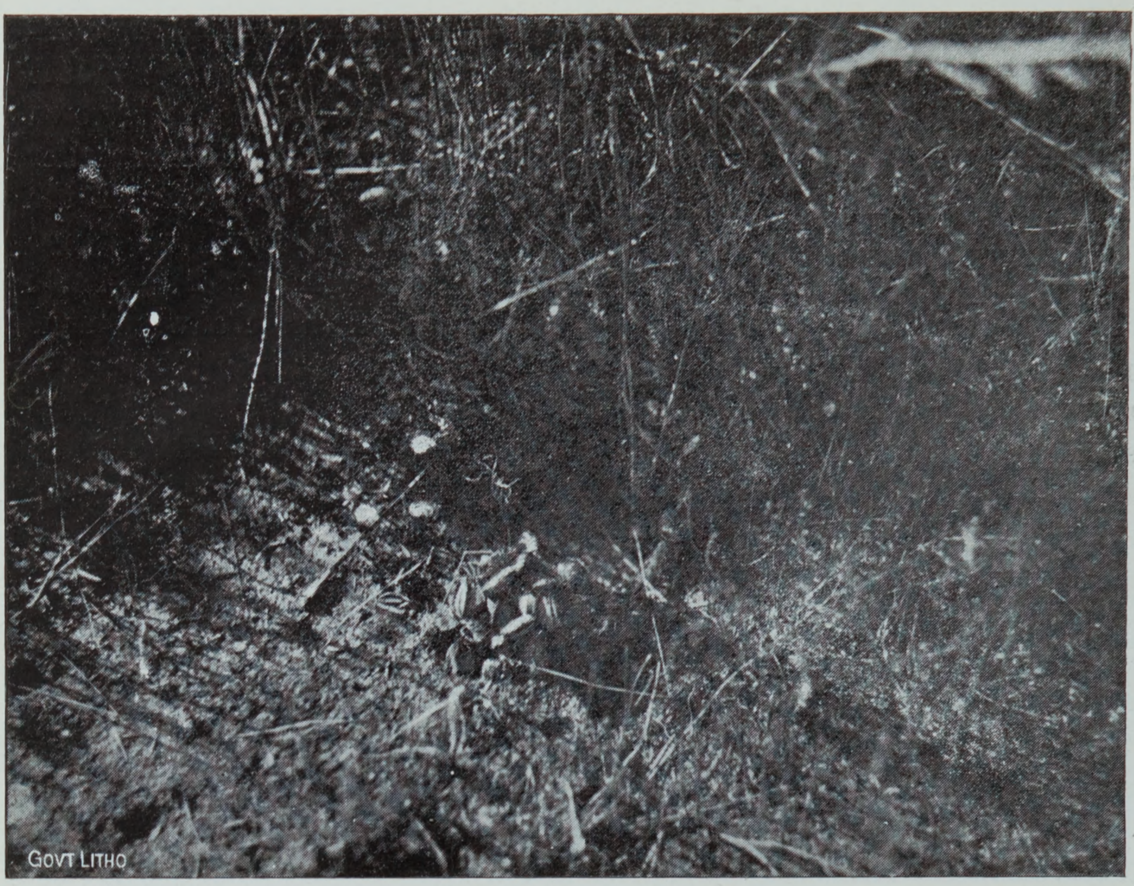

Fig. 3.
Pitcher plants on ground (nearer view).

Fig. 4.
Pitcher plants, young and old specimens.

tion—a similar direction having been taken in the evolution of two morphologically similar structures.

This should accentuate our interest in the study of the chemistry of the two forms.

The Epidermis of the Pitcher.

The inner surface of the Cephalotus pitcher is quite smooth and glossy below the rim. This surface is highly glandular. It extends from the incurved lip down to two lateral kidney-shaped areas, which are very conspicuous (Fig. 5, Lat. p.a.). Each area is raised above the general surface and deeply pigmented. These dark-coloured lateral patches have been named the Lateral Gland Areas. We shall see that this nomenclature is not altogether satisfactory—in fact one may say it is incorrect. With a hand lens, or even the naked eye, it is possible to see small projections along the upper portion of each lateral area. At first sight it might be thought that these were characteristic features of the lateral areas. Such is not the case, although it has been believed that they were. Closer examination reveals the fact that these projections are glands and that they occur over a large area of the surface of the pitcher, although they vary in size and are smaller but more numerous elsewhere. The illustration (Fig. 5) which represents a pitcher cut

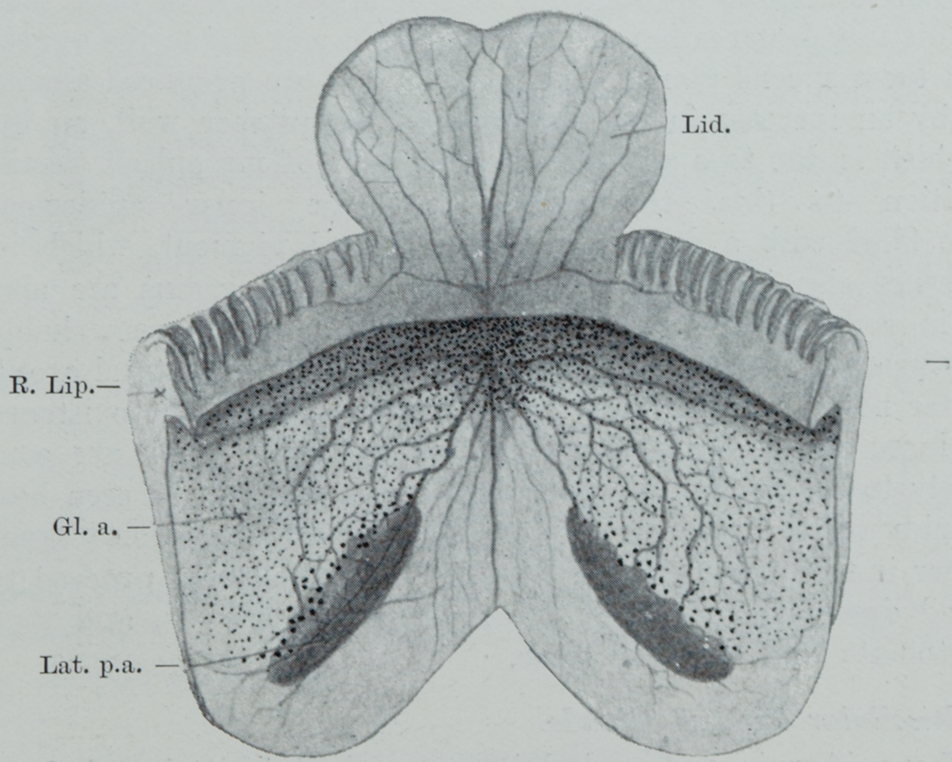

Fig. 5.
Pitcher cut down front and folded to right and left, to show view of internal surface.
Gl. a.—Glandular area ; Lat. p.a.—Lateral pigmented area ; Lid.—Lid ; R. Lip.—Lip of Pitcher.

down the front, the two sides being folded back, illustrates very clearly the distribution of the glands. It will be seen that they are most numerous and smallest just below the incurved lip and in the

region where the vascular bundles from the pitcher stalk enter the pitcher wall. The most obvious and largest glands border the lateral areas but do not extend far upon them (see Fig. 6).

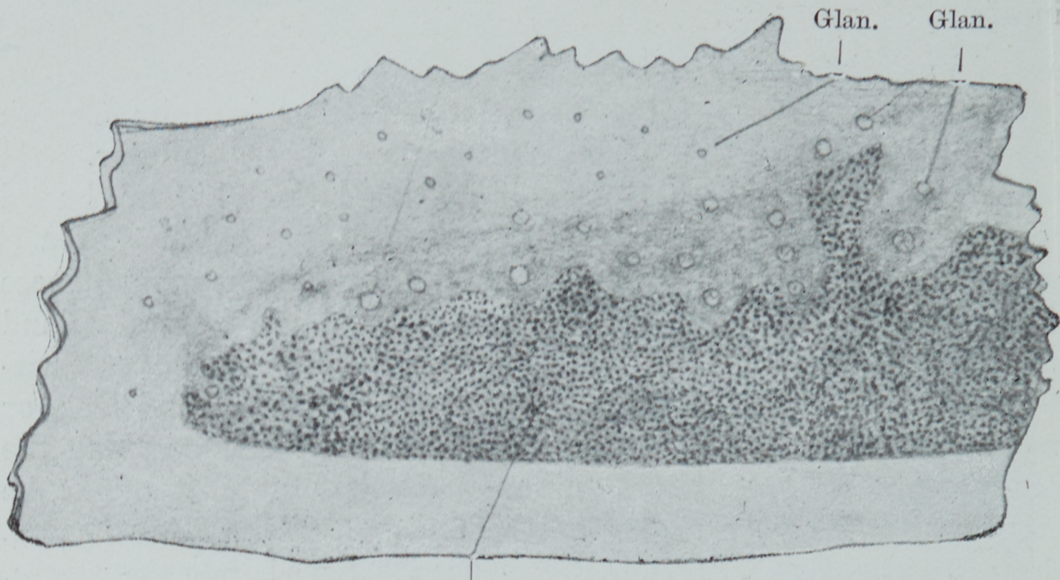

Fig. 6.

View of internal surface of pitcher about the lateral pigmented area.

Glan.—Large glands ; Lat. p.a.—Lateral pigmented area.

Microtome sections through the lateral areas show at once that the very distinct demarcation of these regions is not due to the aggregation of these special glands. The lateral areas are produced almost entirely by an increase in the thickness of the pitcher wall, an increase which is due to a stronger development of mesophyll tissue. In addition to this, the cells below the inner epidermal layer are filled with a dense and deep-coloured pigment, which in places occurs also in the epidermis itself. Starch grains are also present in some of the cells. There is, however, a remarkable feature present in connection with the epidermis of the lateral areas, a character now discovered for the first time. This is the existence of very large numbers of extraordinary "stomata." They are confined solely to the surface of the lateral areas, and can be seen best by stripping off the epidermis (Fig. 10). Below the lateral areas the pitcher is free from glands (Fig. 5). We shall now proceed to a detailed description first, of the multicellular glands, and then of the stomata and stomata areas.

The Multicellular Pitcher Glands.

If the epidermis and underlying mesophyll be stripped from the interior of the pitcher and examined in surface view, the difference in the size of the glands is at once obvious. The appearance presented is illustrated in Figs. 7 and 8. Fig. 7 represents one of the small glands from the surface near the lip of the pitcher. Fig. 8 is one of the large glands from the upper margin of the

lateral pigmented area (Fig. 6, Glan.). No stomata are to be seen in connection with these glands, and there is no sign of any opening. The epidermis is raised very slightly where the gland interrupts its continuity.

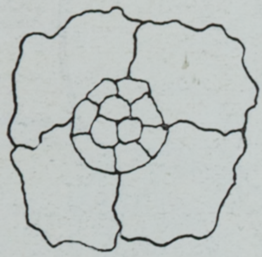

Fig. 7.
Surface view of gland from interior of pitcher near lip (magnified).

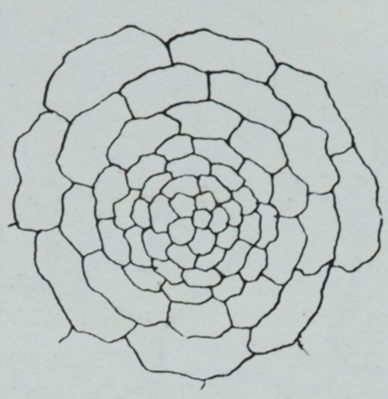

Fig. 8.
Surface view of gland from interior of pitcher near lateral pigmented area (magnified).

In section each gland is seen to be a more or less spherical mass of cells covered over by the epidermis except at one point (a little circular area when observed in surface view). At this point a few of the gland cells reach the surface. No depression or cavity is present into which secretion is poured, nor is any other opening into the gland present. The secretion must pass from cell to cell through the thin walls until the surface is reached and the exudation flows down the walls of the pitcher cavity.

The gland cells contain protoplasm, which is always free from the pigment found in the adjoining cells.

The glands are in close relation with the vascular bundles, and a rich development of spirally thickened tracheids indicates that a good water supply is ensured. On the whole the glands bear a striking resemblance to Hydathodes—the hydathodes of the leaves of *Plumago lapathifolia* for example.

We shall be quite safe in considering these glands as responsible for the secretion of the liquid in the pitchers, for their position prohibits their use as absorbing organs—a large part of the area bearing them is often above the level of the fluid in the pitcher. It remains to be seen whether the specialised lateral regions have any secretory function.

The Stomata of the lateral pigmented areas.

Hamilton states "that the epidermis of the lateral areas is composed of crenate cells in all respects like those of the preceding region" (the inner wall of the pitcher). He misses the significance of the stomata, and only mentions that "at the anterior point of the gland mass where it runs into the ordinary surface there occur some cells which are very puzzling. They are remarkably like stomatas, but there is not always an opening between the guard

cells." Hamilton evidently did not obtain sections of them, and did not observe that the whole surface of the lateral pigmented

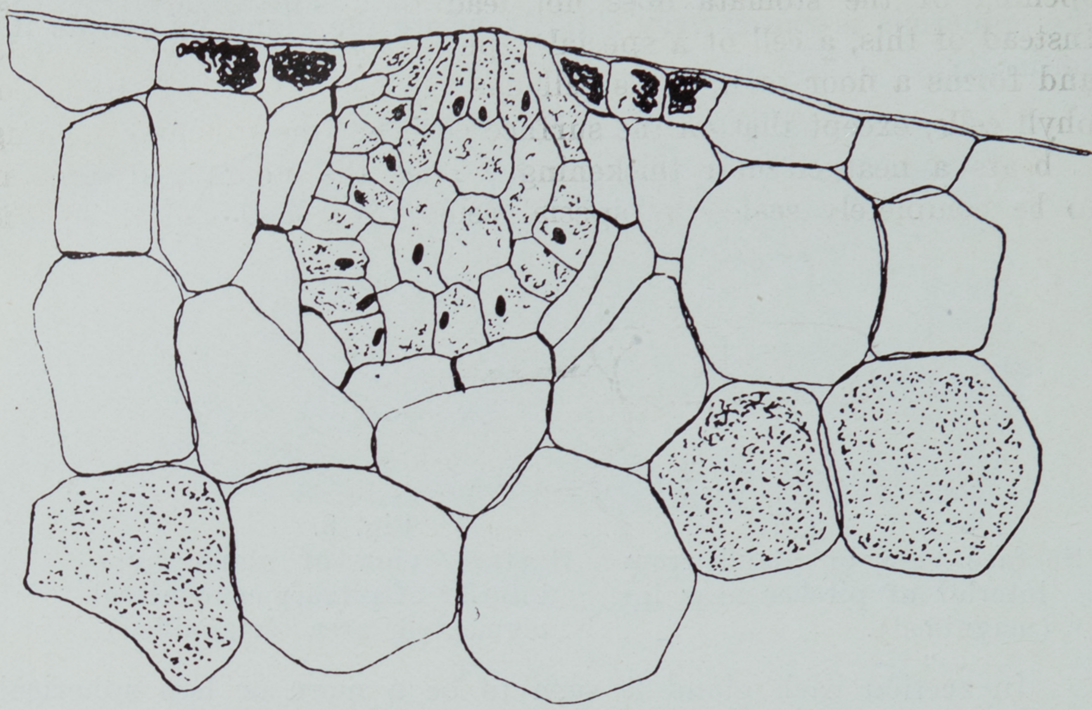

Fig. 9.
Transverse section of pitcher through a large gland.

areas is covered with these structures. Looked at from above, the aperture of the stomata is large compared with the width of the guard cells, and is always almost circular in outline. There is no evidence to show that this shape ever changes. In other words, the aperture between the guard cells is permanently open (see Fig. 10). Sections are required to elucidate the structure, and they are not

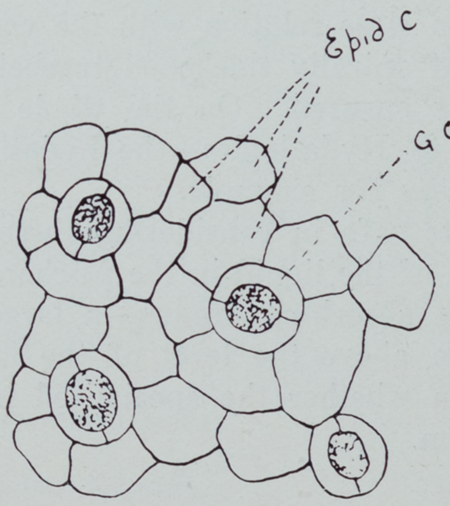

Fig. 10.
Epidermis removed from lateral pigmented area.
Epid. C. = Epidermal cells. G.c. = guard cells.

easy to obtain—hand sections being quite out of the question. In paraffin sections the guard cells are observed to be quite small in relation to the aperture of the stomata and the other epidermal

cells (see Fig. 11). The most striking feature, however, is that the opening of the stomata does not lead to a sub-epidermal space. Instead of this, a cell of a special type lies below the whole stomata and forms a floor to it. This cell has the usual form of the mesophyll cells, except that on the surface covering the stomatal opening it bears a neat circular thickening. Thus the stomata all appear to be completely sealed by special cells. We shall call these the

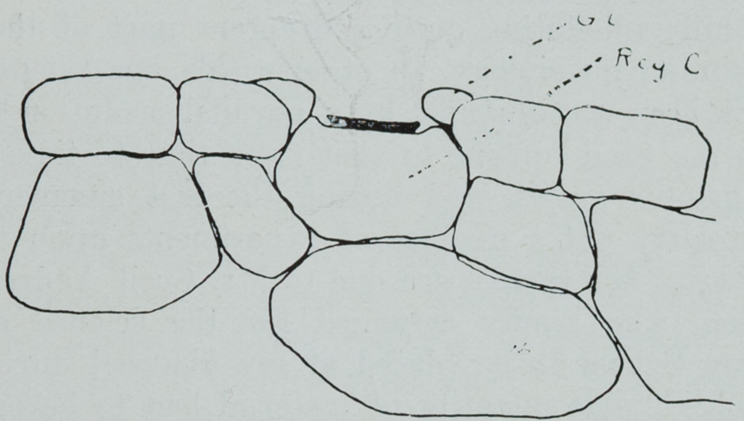

Fig. 11.
Transverse section through lateral pigmented area, through one of the stomata and regulating cells.
G.c. = guard cell. Reg. c. = regulating cell

Regulating Cells (Fig. 11, Reg. C). It must be emphasised that the thickened area on these cells is most definite and sharply marked, and this, in fact, led us to conclude that it was not a mere thickening to occlude the stomata permanently. It will be observed (see Fig. 11) that if the regulating cell is not turgid the thickened area does not touch the guard cells and there is a thin walled area left all round. We conclude from this that the regulation of the stomata opening is carried out, not by changes in the guard cells, but by the movements of the outer wall of the regulating cell. If the pad is forced out by the turgidity of the cell it shuts up the aperture. There are no glands associated with these stomata, and from their specialised structure and localised distribution it may be assumed that they are the absorbing organs of the pitcher. Thus the lateral pigmented areas should be termed the Lateral Absorbing Areas rather than the Lateral Gland Areas.

Further microchemical studies will be necessary before many of the curious features of the Cephalotus pitchers are understood. It becomes, however, more and more evident that the physiology of these pitcher plants is not so simple and easily explained as some botanists have imagined.

The Physiology of the pitchers of Cephalotus Follicularis.

From the year 1874 onwards there has been no inconsiderable discussion amongst botanists on the question of the digestive powers of certain secretions produced by the insectivorous plants. The pitcher plants of the genus Nepenthes have stimulated most of this

discussion, the results of experiments often lending themselves to various interpretations. The West Australian pitcher plant, owing to its more limited range and the absence of trained biologists in Western Australia, has been merely referred to from time to time, suggestions only being put forward. Yet experimental work on this plant offers more of interest than new researches on Nepenthes, inasmuch as it should be interesting to see whether an Australian plant which has evolved on parallel lines to another genus of a different family inhabiting quite a different part of the world, has evolved a similar physiology. In other words, has the parallel evolution in form been accompanied by a parallel evolution in function? It has been my good fortune to visit from time to time the districts where Cephalotus grows, and during the last summer vacation I was able to carry out a number of experiments upon the secretion of the pitchers. My thanks are due to Mr. Cecil Andrews, Director of Education, who kindly arranged for the science room in the Albany State School to be placed at my disposal during the holidays. A considerable quantity of material had to be brought from the University Laboratories, Perth, and the Department of Chemistry aided me considerably in making up certain of the reagents used.

It is well known that the nutrition of typical green plants is autotrophic—the plant by virtue of the pigment termed chlorophyll and the energy of the sunlight is able to build up its food from simple inorganic substances. Carbon is obtained from the carbon-di-oxide of the air, and nitrogen, except in a few cases, is procured from nitrates present in the soil. Certain examples are known where, owing to an imperfectly developed chlorophyll apparatus, a portion of the organic food is taken from the environment, and there is a class of plants the members of which are unable to assimilate carbon-di-oxide at all and consequently depend entirely upon organic materials. These are known as heterotrophic plants, the fungi being excellent examples. But all the insectivorous plants we have named possess leaves and chlorophyll and have normal roots. At first sight, therefore, the possession of an elaborate apparatus for the capture and ingestion of organic matter seems quite uncalled for. This feature is rendered still more mysterious by the fact that many of these plants have been cultivated in laboratories and grown over long periods without the provision of insects or other organic matter. Darwin cultivated Droseras, and we have had specimens of Cephalotus for twenty-seven months, during which time new leaves have developed and numerous new pitchers have been formed—the plants also flowered in the laboratory. No insects were utilised by the plant at any time during this period.

In specimens of Cephalotus obtained from Albany the pitchers were, with few exceptions (and these were newly opened pitchers),

full of insect remains; the insects most common being ants, flies, and beetles. Other insect groups were represented and more odd specimens were occasionally found, such as fly larvæ, frog spawn, and snails.

The pitchers of Nepenthes are found similarly loaded, even small birds being sometimes captured by the plant. This, however, is an accident, the birds being either after the water or the captured insects.

The first observations of the digestive power of the Nepenthes pitchers were made by the famous botanist Sir Joseph Hooker, and the results were made public at the 1874 meeting of the British Association at Belfast. Hooker found that "after twenty-four hours' immersion the edges of cubes of white of eggs were eaten away and the surfaces gelatinised, fragments of meat were rapidly reduced, and pieces of fibrin weighing several grains dissolved and totally disappeared in two or three days." It is noteworthy, however, that even at this stage Hooker did not jump to the conclusion that the digestion was wholly due to the liquid secreted by the glands of the pitcher, although he does not definitely state what other agency he had in view. Hooker's results stimulated inquiry, and in 1875 Lawson Tait stated that he had abstracted a substance closely resembling pepsin from the pitcher plant liquid. The next year, 1876, brought further information, Gorup-Besanez announcing that the liquid from the pitchers was neutral or acid according as to whether the pitchers were unstimulated or stimulated, and that, whilst the acid fluid digested fibrin within two hours at 20 C., the neutral liquid had no effect even after 24 hours. This worker demonstrated also the presence of peptone (a product of the peptic digestion of proteids) at the end of his experiments. In 1877 Vines, who had conducted a most careful series of experiments on Nepenthes, published the first paper on his investigations. He agreed with the previous workers that the fluid secreted by the pitchers contained a digestive ferment or enzyme which, like the pepsin of the human stomach, acted upon proteid in a slightly acid medium. These views were held for a few years until in 1890 Dubois, experimenting with fluid from various species of Nepenthes, came to a different conclusion. This investigator stated that if the fluid was taken from closed pitchers by means of a sterilised pipette it had no action on cubes of egg albumen even at temperatures between 35° and 40°C. He then examined the open pitchers and, as a result, stated that the disintegration of proteids was due, not to a digestive enzyme, but to the action of bacteria. He concluded that Nepenthes was not really a carnivorous plant and that the obvious digestion was only a false digestion. The same point of view was taken by a Russian scientist (Tischutkin) in 1892. The opposition brought forward further discussion and the next worker,

Goebel, returned to the point of view taken up by Hooker and Vines. Vines took up the subject again and conducted further researches in 1897 along lines which precluded the action of bacteria. As a result of this work our knowledge of the Nepenthes pitcher fluid stands somewhat as follows:—

1. Digestion of fibrin and other proteids takes place if the pitcher fluids are acidulated—even if substances such as prussic acid are present which prevent the action of bacteria.
2. The pitcher fluid varies from neutral to distinctly acid, but that of open pitchers in which insects are present is as often neutral as acid.
3. Only a minute quantity of proteid is present in the pitcher fluid.
4. The products of digestion are not true peptones, and further investigations are required.

Now let us turn to Cephalotus. In Pfeffer's "Physiology of Plants" the following statement is made which concerns Cephalotus:—

"In the pitchers of Sarracenia, Darlingtonia, Cephalotus, and probably also in the bladders of Utricularia, *no* enzyme is secreted, but nevertheless nitrogenous products set free by bacterial decomposition may be absorbed."

Nepenthes is put in a different category from Cephalotus. Geddes states:—"The recent researches of Professor Vines (1897), although ascribing the digestive powers of Nepenthes to a true proteolytic ferment in the presence of an acid, yet agree with those of Professor Dubois in regarding all other cases of so-called digestion amongst pitcher plants, with the possible exception of that of Cephalotus, as due to putrefaction set up by the microbes always present in the pitcher fluid." We have here a statement which sums up pretty well the present position with regard to Cephalotus—a position of uncertainty which is not based upon any experimental work whatever.

During the month of September last year work was commenced on pitcher plants at Albany. In the first experiments the fluid was removed from the pitcher by a sterile pipette, and brought back in sterile tubes to the laboratory. Fibrin was chosen as the proteid for digestion, and fresh fibrin was obtained through the aid of the Perth Public Health Department. It is removed from sheep's blood by whipping. Test tubes were set up containing—

1. Fluid from pitchers + fibrin.
2. " " + fibrin + antiseptic.

Several experiments of this kind were carried out, but in all cases no alteration of the fibrin took place even after several days. An-

other series of experiments were then set going in which marked pitcher plants in the swamps were fed with pieces of fibrin. These plants were visited at frequent intervals and the condition of the fibrin in the pitchers examined, as also the composition of the contained fluid. The results were negative—no digestion taking place nor any alteration, except in one case, where putrefaction had resulted in the breaking down of the fibrin. As putrefaction is not found in the pitchers full of insect remains, and as it was exceptional here, this solitary case was not considered of much importance. Finally a number of pitchers were chopped up and extracts made with water and glycerine. These extracts were used for the digestion of fibrin. The results so far as naked eye observations were concerned were again negative, and chemical tests were rendered practically impossible with the means at my disposal owing to the colour changes in the pigment which came out in the extracts. This first inquiry, which was carried out rather empirically, only stimulated my interest, so that a laboratory was fitted up in the summer and the question was tackled with a better equipment for carrying out the work.

Pitcher plant fluid was obtained with the same precautions as before from plants living about a mile from Albany. The solution which usually contained a considerable quantity of insect bodies was brought straight back to the laboratory and filtered. The fluid was usually quite neutral to litmus, but there was a tendency to show a slight acidity when phenol phthalein was used as an indicator. Four tubes each containing 2ccs. of pitcher plant fluid were set up.

Tube No. 1 contained fibrin and pitcher fluid alone.
Tube No. 2 contained fibrin and pitcher fluid and 1 drop HCN.
Tube No. 3 contained fibrin and pitcher fluid and 0·1 CC. Decinor. HCl. and 1 drop HCN.
Tube No. 4 contained fibrin and pitcher fluid and 0·2 CC. Deci. HCl. and HCN.

The experiment was set going at 4 p.m. Thursday.

On Friday morning, 9.30 a.m., no digestion had taken place in Nos. 1 and 2, but in No. 3 the fibrin was digested, and in No. 4 it was partly digested. This was the first indication of digestion taking place. The two first tubes were left standing and by Sunday digestion had also taken place in tube No. 1, but *not* in No. 2. The difference between these two tubes was that No. 1 contained no HCN., and since the smell of putrefaction was well apparent there the results of the experiment can be easily explained.

Digestion of the fibrin had only taken place in the acidulated pitcher fluid, but it had taken place there despite the action of an antiseptic which prevented the growth of bacteria. In the absence of both acid and antiseptic, putrefaction had taken place whilst

in the presence of HCN, but no acid whenever there was no digestion. These experiments were repeated with controls and extended. Tubes containing fibrin and pitcher fluid, but with neither acid nor HCN, were repeatedly set going. The results were always the same, putrefaction took place due to bacterial action and the fibrin was broken down. This action, however, took some time and usually no change was observed during the first day or two. The absence of this reaction in the experiments carried out in the winter is to be explained by the low temperature in the unheated room used as a laboratory.

It will be noticed that the pitcher fluid which had been acidulated broke down the fibrin and brought it into solution very rapidly indeed—much more rapidly than when bacteriological action was allowed to take place alone. Controls showed that a proper care in the addition of HCN effectively prevented bacterial action whilst treatment of fibrin with acid and HCN alone in another set of control experiments enabled us to determine exactly what was due to the pitcher fluid.

Starch solution was apparently left unchanged, at all events the starch to a large extent remained and there was no difference in the colour reactions between tubes with pitcher fluid and control tubes with plain water.

Amongst the series of tests the following may be mentioned as an example:—

Tube 1—Fibrin + 5CC. Pitcher Fluid + HCN. No acid.
Tube 2—Fibrin + 5CC. Pitcher Fluid + HCN + 0·2 CC. N/10 HCl.
Tube 3—Fibrin + 5CC. Pitcher Fluid + HCN. + N/10 Alkali.
Tube 4—Fibrin + Water + HCN + 0·2CC N/10 HCl.
Tube 5—Fibrin + Water and HCN. No acid.

Tubes 4 and 5 were controls to determine the effect of the N/10 HCl upon the fibrin. The results were as follows:—

1. No digestion took place.
2. Digestion of the fibrin in a few hours.
3. No digestion.
4. No digestion but fibrin cleared and swollen.
5. No digestion.

It will be seen that the acid alone was incapable of bringing about the results observed in the tubes to which pitcher fluid and acid had been added. Thus in the fluid from the Cephalotus pitchers there is ample evidence of the presence of a substance which readily digests proteid in the presence of small quantities of acid. This is the first record of such for the pitcher plant of West Australia.

Another point to be made, which is equally interesting, is that the conditions under which we have observed digestion taking place

are practically identical with those discovered by Vines to apply to Nepenthes.

Now Vines concluded in the case of Nepenthes that digestion, as we have seen it taking place (in acid media *in vitro*), was proof of the function and mode of function of the pitcher secretion. It seems likely that this conclusion is somewhat premature. The fact that in an acidulated medium in a glass tube digestion takes place does *not* prove that the same takes place alone, if at all, in the pitchers of the plant, especially since no certain digestion can be observed in the absence of acid. The pitcher fluid was taken from stimulated pitchers, *i.e.*, pitchers containing numbers of insects, consequently it would be natural to suppose that the fluid would digest without the addition of acid. This does not appear, however, to be the case in *vitro*. We might therefore even go so far as to say that the presence of a true digestive ferment in the pitcher fluid was an accident and that it was not used normally by the plant. Whether such a statement be correct or not it is certainly not altogether far-fetched, for ferments sometimes occur in animal and plant fluids which may not be used for digestion. Neither Vines' experiments nor those of the author up to date prove conclusively that bacteria are *not* at work in the pitchers. And as a matter of fact bacteria are normally present in the pitchers and have been isolated in the course of this work.

The constitution of the pitcher fluid requires further investigation. The following tests have been applied to that from Cephalotus pitchers:—

1. Litmus—Neutral.
2. Biuret test—No result.
3. Millon's Re-agent—No. ppt.
4. HNO_3—Slight ppt.
5. Na HO.—ppt.

The tests serve to indicate that the pitcher plant fluid contains very little protein, a rather extraordinary result considering the presence of insects in the fluid. One would have expected a marked biuret reaction.

Here again, however, the results of this Cephalotus research resemble those of Vines on Nepenthes. "The general conclusion at which I arrive is that either the enzyme is not a proteid or, if it is, it is present in extremely minute quantity, though it is difficult to accept this alternative in view of the remarkable digestive activity of the liquid." (Vines.)

The products of digestion when it occurs in vitro in the presence of acid are always characteristic, and the resultant fluid gives a marked pink biuret reaction. Such digestion is, therefore, rather like peptic digestion resulting in peptone-like products. This, how-

ever, must only be considered as tentative. It is certainly evident that up to the present the complex nature of the bio-chemistry of the pitcher plants has not been suspected. Would it be possible to account for the presence of the pitchers and the extraordinary glands secreting fluid, without reference to insect feeding?

It has already been suggested that the fluid of some pitcher plants is secreted and kept in the pitchers to be re-absorbed when required by the plant. Then, again, the secretion of water by hydathodes has been explained as of great use to plants which are living in such a moist atmosphere that little transpiration, *i.e.*, evaporation from the leaves can take place. Owing to the secretion of water by such glands a water current may be set up in the plant when it would otherwise be very feeble. Now, Cephalotus grows under conditions which are most unfavourable for transpiration. It is a low plant, sheltered from air currents and it is found on extremely moist ground. The retention of the water in the pitchers would, however, require explanation, and I think it straining the point too far to imagine that this fluid is required for reabsorption during the dry weather. The dry season is very short at Albany, and the ground, where the pitcher plants grow, never becomes very dry so far as I know. We may consider this another possible reason for the presence of the glands and the pitcher fluid, but it does not seem sufficient to account altogether for the evolution of an elaborate pitcher which usually contains insects, and seems specially fitted for their capture.

Is there any reason why our pitcher plant should require food in organic form? We have already shown that it can be cultivated without it. The fact that the pitcher plant can be grown without the provision of insect food does not form a stumbling block to a belief in its carnivorous propensities, for Busgen, in 1888, showed that Utricularia would grow without animal food, but that the provision of the latter resulted in double the development. It was demonstrated also in 1883 that Drosera could be grown apart from insects, but that plants allowed to capture and digest insects were 1½-3 times the dry weight of those not fed in this way and they produced more flowers and fruit. We hope to have a similar series of experiments set going with Cephalotus in order to discover whether there is any marked difference between plants fed with insects, etc., and those which have been kept without organic matter.

In the meantime it must be pointed out that very many of the carnivorous plants grow on somewhat boggy, peaty soils. This is particularly the case with the sundew in Great Britain and Europe and our Western Australian pitcher plant. Now, if there is some factor common to the environment of these plants which are in many ways different but agree in the physiological feature we are studying, this common factor may explain the carnivorous habit.

It is already known that there is some difficulty in obtaining Nitrogen from this peaty soil, and it has been suggested on this account that the carnivorous habit is to be associated with the procuration of an extra supply of Nitrogen in the form of organic compounds. We have, therefore, two theories, both of which will fit our pitcher plant.

Summary.

The following may be taken as a brief summary of what is known to-day of the West Australian Pitcher plant—*Cephalotus follicularis*:—

1. The pitchers capture insects, and in large quantities.
2. The capture of insects is not absolutely necessary for the growth of the plant and the formation of new parts or the development of flowers.
3. The fluid in the pitchers contains a digestive ferment which will break up proteids into peptone-like bodies in a very short time in the presence of acid.
4. It has not been shown (nor is it true for Nepenthes) that this is the mode of digestion actually taking place in the pitchers, and as a matter of fact non-acidulated pitcher fluid does not digest proteid, or, if so, very slowly in vitro.
5. It is possible that digestion in the pitchers is due to the action of the ferment and that this digestion takes place very slowly.
6. The environment of the West Australian pitcher plant suggests that the development of pitchers with glands serves two purposes—
   (a.) It provides for a water current in the plants by the secretion of water from the pitcher walls. This would be an advantage, seeing that the plants are unfavourably situated for transpiration.
   (b.) It provides another method for the obtaining of nitrogen—a necessary element procured with difficulty from peaty soils.
7. Experiments are now being arranged to determine the effects produced by feeding the pitchers with insects and different organic compounds, comparisons being made with other specimens growing without such additions.

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